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Impact of Primary Sulfate and Nitrate Emissions from Selected Major Sources Phase 1. Coal-Fired Power Plant

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IMPACT OF PRIMARY SULFATE AND NITRATE EMISSIONS FROM SELECTED MAJOR SOURCES

Phase I. Coal-Fired Power Plant

by

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This report covers Phase one of a two phase study of the near source impacts of primary sulfate and nitrate emission sources. The phase one portion of the study was an investigation of the impact of a coal fired power plant burning high sulfur coal. The study was designed to measure the increases in the ground-level ambient air sulfate and nitrate concentrations resulting from the plant's emission within ten kilometers of the plant. The field sampling involved concurrent sampling at the source and in the ambient upwind and downwind of the plant for particulate matter, sulfates, nitrates, sulfuric acid, nitric acid, SO_2, and NO_x.

The tests were conducted in the vicinity of the Scholz Generating Station of Gulf Power Co., which is located in a lightly industrialized area of north-western Florida. The plant consists of two 50 megawatt units fueled by coal which has an average sulfur content of 3.5 percent. The concentrations of H_2SO_4, SO_2, NO_x and particles were respectively about 5 ppm, 2000 ppm, 450 ppm, and 50 mg/m3.

The plant was the dominant source of SO_2 in the area. Concentrations of over 500 ppb were measured in the plume downwind of the plant with average concentrations over a six to ten hour period downwind reaching values of proportional to the SO_2 concentrations.

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ABSTRACT

This report covers Phase One of a two phase study of the near source impacts of primary sulfate and nitrate emission sources. The phase one portion of the study was an investigation of the impact of a coal fired power plant burning high sulfur coal. The phase two study was an investigation of oil-fired power plant, sulfuric acid plant and a pulp mill. The study was designed to measure the increases in the ground-level ambient air sulfate and nitrate concentrations resulting from the plant's emission within ten kilometers of the plant. The field sampling portion of the study was carried out during January and February of 1981.

The field sampling involved concurrent sampling at the source and in the ambient upwind and downwind of the plant for particulate matter, sulfates, nitrates, sulfuric acid, nitric acid, SO_2, and NO_x.

The tests were conducted in the vicinity of the Scholz Generating Station of Gulf Power Co., which is located in a lightly industrialized area of north-western Florida. The plant consists of two 50 megawatt units fueled by coal which has an average sulfur content of 3.5 percent. Each unit is equipped with a high efficiency electrostatic precipitator for particulate emission control; oxides of sulfur and nitrogen are not controlled. The flue gases from the two units are discharged through a common 47.5 meter stack. The total gas flow for the combined units was about 220 cubic meters per second when both units were at full load. Particulate concentrations in the exhaust gases were about 50 mg/DNCM. The concentrations of H_2SO_4, SO_2, and NO_x were respectively about 5 ppm, 2000 ppm, and 450 ppm.

The average concentration of total suspended particulates in the ambient was about 40 $\mu g/m^3$. Factor analysis based on elemental analyses of material collected by high volume sampling, the plant's flyash and local soil samples indicates that wind blown soil is the dominant source of the ambient particulate matter.

In the raw data, sulfate concentrations averaged about 2 to 2.5 $\mu g/m^3$ upwind of the plant and 4 $\mu g/m^3$ downwind of the plant. After compensating for the actual area impacted by the plume compared to the total area within the 10 Km radius of the study, the plant's contribution to the total sulfate burden in its immediate surroundings represents an areawide increase of about 15 percent over the background levels. The bulk (approximately 95%) of the sulfate attributable to the plant was in the form of sulfuric acid. In the plume, the ratio of sulfate attributable to the plant to SO_2 was approximately twice the ratio of sulfate to SO_2 in the stack, indicating a near source conversion rate of SO_2 to sulfate of 0.25 percent per hour, if the conversion is assumed to take place at a constant rate. The data would also support the possibility of a more rapid conversion rate immediately after discharge of the flue gases to the atmosphere, followed by a slower rate thereafter.

The total nitrate concentration in the ambient averaged about 1.1 $\mu g/m^3$ with no clear trends with respect to concentrations upwind and downwind of the plant. The ambient nitrates were dominated by nitric acid, the bulk of which appears to have resulted from vehicular sources with the Scholz plant contributing about 15 percent of the total.

The plant was the dominant source of SO_2 in the area. Concentrations of over 500 ppb were measured in the plume downwind of the plant with average concentrations over a six to ten hour period downwind reaching values of about 150 ppb. NO_x concentrations downwind of the plant were roughly proportional to the SO_2 concentrations. Background concentrations of both SO_2 and NO_x were below the detection limits of the analyzers on most occasions (about 5 ppb and 1 ppb, respectively). About 40 percent of the NO_x in the plume was in the form of NO_2 while no more than 5 percent was NO_2 in the stack.

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SECTION 1

INTRODUCTION

This report covers the work performed in phase one of a two phase study entitled "Assessment of the Impacts of Primary Sulfate and Nitrate Emissions on Air Quality in the Vicinity of a Coal-fired Power Plant, Oil-fired Power Plant, Sulfuric Acid Plant, and Pulp Mill". The phase one study was concerned with the impact of a coal-fired power plant. Phase Two concerned oil-fired power plants, sulfuric acid plants and pulp mills.

The study was conducted as a joint research project of Southern Research Institute (SoRI) and TRC Environmental Consultants, with TRC serving as a subcontractor to SoRI. Source emissions data, ambient particulate elemental composition by particle size, and ambient sulfuric acid concentrations were the responsibility of SoRI. TRC was responsible for obtaining ambient data concerning meteorology, total suspended particulate concentrations, nitrate and nitric acid, and the gaseous species SO_2, NO and NO_2. The phase one study was conducted during late January and early February, 1981 at the Scholz Steam Plant of the Gulf Power Company, located in north-western Florida.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The Scholz Steam Plant, around which this study was performed, was found to be the dominant source of gaseous sulfur and nitrogen oxides in the area. However, it was found to contribute only about fifteen (15) percent of the ambient particulate sulfate and nitrate burdens. The major contributor to the ambient particulate nitrates appeared to be automotive in origin while the sulfates appeared to be primarily associated with wind blown soil.

The plant's oxides of nitrogen emissions were almost entirely in the form of NO in the stack, while approximately 40% had oxidized to NO_2 within two to five kilometers of the plant. The ratio of sulfate to SO_2 associated with the plant's emissions was found to be about twice as large in the ambient air as in the stack. This could have resulted from continuous oxidation of SO_2 at a rate of about 0.25%/hr but the data would also support a much more rapid oxidation rate immediately upon discharge from the stack followed by a slower rate thereafter. Approximately 90% of the sulfate emissions from the plant were in the form of sulfuric acid. The available data do not indicate that any significant neutralization took place before the plume reached the sampling sites.

The elements selenium, arsenic, scandium, and uranium were found to be the best markers for the plant's emissions in the plume downwind of the plant. Other elements in the particulate emissions tended to have high concentrations in windblown soil, which was the major particulate source in the area, and were thus less useful in differentiating the plant's emissions from other sources. Windblown soil also appeared to be the major source of sulfates within the study area. It is possible that some, or much, of the soil sulfate may have originated in the plant's emissions and represent a resuspension of previously deposited material. The fraction of the sulfates attributed to the plant here is solely that due to the direct emissions.

Several lines of potentially rewarding investigations were suggested by the results of this work, among which are the following.

The data obtained in this study support the possibility of an SO_2 to sulfate conversion rate with a changing rate constant during the period immediately after discharge from the stack with the rate constant having its greatest value near the time of discharge. The sulfate burdens out to moderately long distances downwind of the plant could be influenced significantly by such a period of initially rapid oxidation. Therefore a study of the SO_2 to sulfate conversion rates in the plume at short distances (times) after discharge might prove to be worthwhile.

Further study of automotive vehicles as nitrate sources are indicated as the data here suggest that automotive sources dominated in the local nitrate in spite of the power plant being the dominant NO_x source in the area.

Finally, in future studies of the type carried out here and in studies of acidic deposition, fine particulate fractions of local soils should be analyzed for nitrate and sulfate content. Wind-borne soil frequently dominates in the ambient air particulate burdens, as was the case in this study, and if the local soils contain significant sulfate or nitrate concentrations they can be major contributors to local deposition.

SECTION 3

BACKGROUND

The development of prudent emissions control strategies on both local and national scales requires characterization of the numerous pathways taken through the atmosphere by gases and particulate matter from sources to eventual receptors. Gases emitted into the atmosphere disperse and react directly with receptors at ground level or are converted to particulate matter through homogeneous gas phase reactions or through reactions with pre-existing particles (including adsorption). Particulate matter leaves the atmosphere through turbulent diffusion (or dispersion), precipitation, and dry deposition. Aerosol particles tend to grow in size through reactions with gases and by agglomeration.

Sulfur and nitrogen compounds are of particular concern because of their preponderance in combustion flue gas and as decomposition products of other process streams. High levels of SO_2, NO, NO_2, and various sulfates and nitrates are found in ambient air associated with industrial activity and areas with high automotive traffic densities.[1-12] Serious deterioration of the environment has been linked with these compounds.[13-17] The dangers of sulfur emissions have been suspected for centuries.[18] In 1964, SO_2 emissions began to be regulated in this country. The use of high sulfur fuels was inhibited and taller stacks were employed to improve local air quality. This improved the measured levels of local SO_2. However, ambient sulfate levels have not been substantially improved. Furthermore, correlation studies of respiratory infections with SO_2 and sulfate levels have linked health problems to sulfate levels more directly than to SO_2 levels.[17] Thus it is important that the specific contributions of these aerosols to the atmosphere be delineated, and controlling mechanisms and local and long range concentrations and transport be determined.

Much research work in recent years has dealt with this problem. Numerous mechanisms have been identified at sources and in ambient measurements. However, the relative importance of the mechanisms are not understood, because they are apparently the dependent upon geographical location, meteorological conditions, and the specific nature of the sources.

Research and analysis of air quality treats aerosols as two types because of practical reasons related to measurement and the basic differences in the physical and chemical natures of process streams and ambient air. A primary aerosol is the particulate matter exiting the source, including pre-existing vapors such as sulfuric acid which become supersaturated and condense in the near source plume. A secondary aerosol is formed by gas-to-particle conversion due to a chemical reaction. Practically speaking, secondary aerosol has been considered as that formed over long periods in the ambient air and measurable at great distances from the sources. However, significant oxidation of SO_2 to particulate sulfate is sometimes found in the vicinity of sources.[20-26]

One of the important questions to be addressed in this project was whether increased primary aerosol or secondary aerosol formation is responsible for the higher sulfate/SO_2 ratios observed now in the atmosphere relative to a decade ago. For example, the use of taller stacks in recent years may have increased the residence time in the atmosphere causing greater oxidation of SO_2 to sulfate. On the other hand, the shift from high sulfur to low sulfur fuels such as oil may be the important factor due to higher concentrations of catalytic agents such as vanadium in the current fuels. It has been verified that fuel components other than sulfur and nitrogen are important in primary sulfate formation. For instance, sulfate levels emitted by oil- fired power plants are typically five-fold greater than those of coal-fired plants with equivalent sulfur contents.[19,20,21,26,27]

The sulfur content of fuels plays an important role in both primary and secondary aerosols. Most of the sulfur leaves the combustion process as SO_2, however, sufficient further oxidation occurs that sulfate is frequently the major component of the primary aerosol. No convening evidence is known for significant nitrate formation in the combustion streams. N_2 in the intake air and nitrogen in the fuel are oxidized to NO and NO_2, the latter comprising less than 10% of the total NO_x. These nitrogen compounds are of concern because of nitrate formation in the atmosphere and associated health[17] and acidification problems.

Most current studies on the mechanisms of sulfate and nitrate formation and transport in the atmosphere have dealt with, or are addressing the problems of long range transport. However, a significant portion of the problems associated with these compounds may arise in the near source vicinity. The program described here was intended to investigate several facets of this near source portion of the problem.

SECTION 4

PROGRAM DESCRIPTION

SOURCE

The Scholz Steam Plant, operated by Gulf Power Company and located on the Apalachicola River in north-western Florida, approximately 65 km (40 mi.) west of Tallahassee, was selected as the site for the phase one study. The location of the plant is shown in Figure 1. This plant was selected because it utilized a high sulfur fuel; was not equipped with scrubbers (which would reduce the sulfur oxide concentrations in its emissions); and it was located in an isolated, non-industrialized, rural area near a seacoast. The location was important because it was desired that this study be carried out in an area in which the confounding influences of other sources would be minimal.

The Scholz Plant consists of two coal-fired generating units, each of which has a nominal peak output of 50 mw. The boilers are B&W Radient, wall-fired pulverized-coal types. The coal is supplied by mines located in northern Alabama and typically has a sulfur content of three (3) percent. Particulate emissions from each unit are controlled by very high efficiency electrostatic precipitators (ESP's). Oxides of sulfur and nitrogen are not controlled. The flue gases from the two units are discharged to the atmosphere through a common stack which has a height of 45.7 meters (150 ft) and a diameter of 4.1 meters (13.5 ft). Each unit is equipped with continuous emission monitors for NO, SO_2, O_2, moisture, and opacity. A pilot scale limestone/dual-alkali SO_2 scrubber was in operation on a sidestream from Unit 1 throughout most of the study. When operating, the scrubber treated between 10 and 30 percent of the flue gas from Unit 1, or 5 to 15 percent of the combined flow from the two units.

SURROUNDINGS

The terrain surrounding the Scholz Plant is flat to rolling with no major elevation changes within the study area. Hills in the area rise between 50 and 150 feet above the level of the river. The surroundings are essentially rural in character. Major traffic arteries within the study area are Interstate 10, which runs E-W about 5 km to the south of the plant, and U.S. 90, which runs E-W about 5 km north of the plant. The small

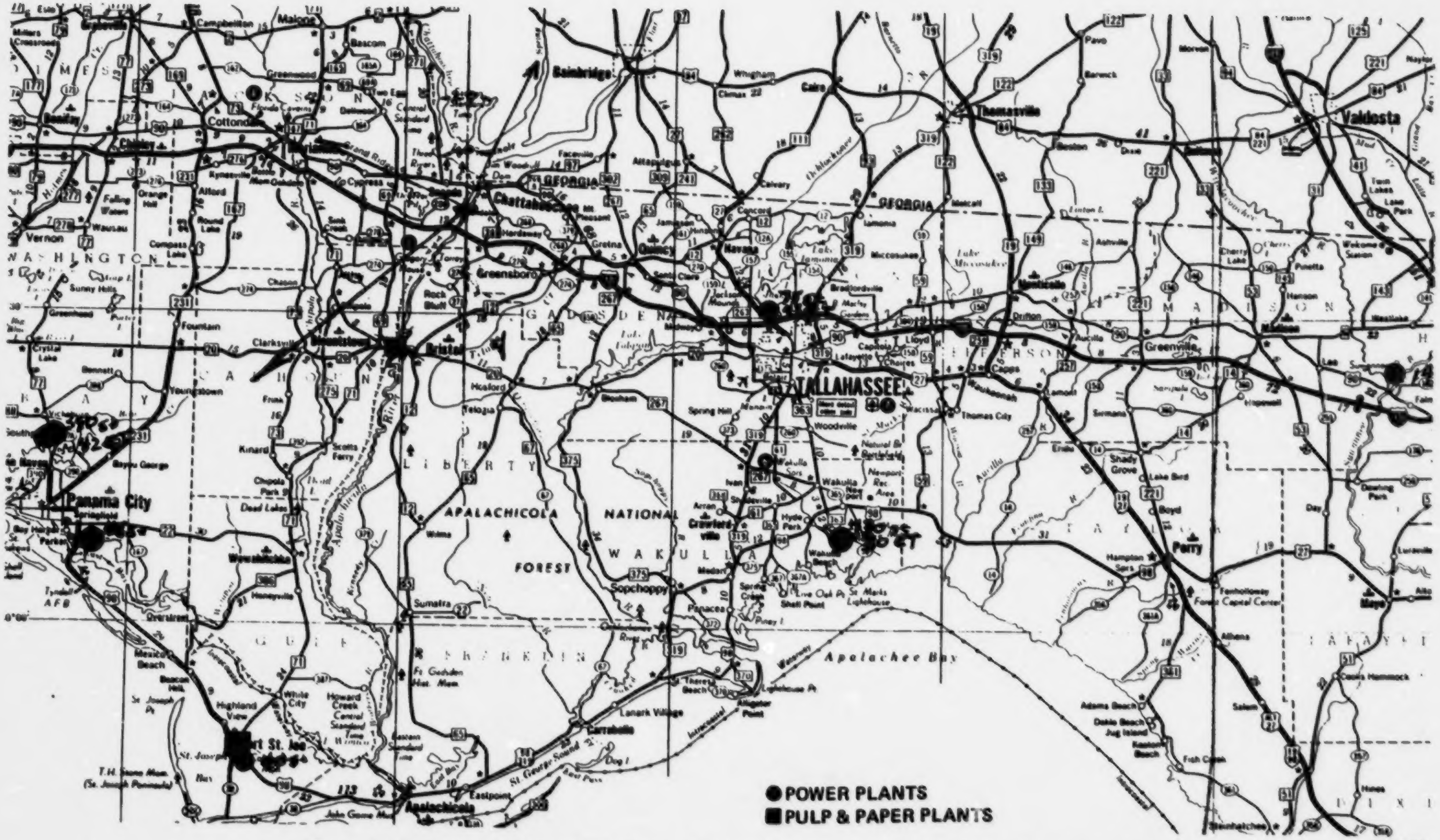

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Figure 1. *Location of the Scholz Steam Plant and other significant industrial sources within 100 km of the plant.*

towns of Sneads and Chattahoochee lie, respectively, about 7 km NW and 9 km NE of the plant. There are no significant industrial plants within the study area other than the Scholz plant. Two pulp and paper plants and five coal or oil fired electric generating plants are located at distances varying from 60 to 90 km from the Scholz plant and one small pulp and paper plant is located about 30 km to the southwest. The wind directions during the tests were such that only one of the pulp and paper plants and one of the power plants were likely to have any detectable impact on the study area. The locations of all the aforementioned plants are shown in Figure 1.

A map of the immediate area around the plant in which the ambient sampling was carried out is provided in Figure 2. With the exceptions of I10, U.S. 90, and Routes 271, 269, and 286, the roads within the study area were unpaved. Much of the land to the south and east of the plant is swampy, and road access in these directions is limited. This caused some difficulty in finding suitable sampling sites for the ambient sampling stations when the winds were from the north and west. Fortunately, such winds were infrequent during the test period.

PARAMETERS OF INTEREST

The primary variables of interest in this study were of course, particulate and gaseous sulfates and nitrates in the ambient air which were directly or indirectly the result of emissions from the Scholz Plant. Further, it was desirable to differentiate between sulfate and nitrate salts and sulfuric and nitric acid. Thus data was needed on the ambient and source concentrations of these variables and their precursors.

In order to separate the contribution of the plant from those of other sources, knowledge of the background concentrations of the target variables was also required together with the identification of other potential contributors. The species of interest are reactive and are probably not conserved, even over the short transport distances involved in this study. Therefore, another tracer of the plant's emissions was desired, from which dilution factors might be obtained for the plume downwind of the plant. A signature based on the emission rates of a number of chemical elements in the particulate matter emitted by plant was selected for this purpose. Because particle deposition rates are size dependent, the emission signature to be used was one in which the composition of the particulate matter was separately determined for a number of size classes. By doing this, the coarser particles, which are depleted more rapidly in the plume, could be discounted in the tracer analysis.

The final test matrix included the measurement of the following in the source and ambient, respectively; sulfuric acid, sulfate salts, sulfur dioxide, particulate nitrates, nitrogen oxide, nitrogen dioxide, total particulates; and elemental composition by particle size. Measurements in the ambient included all of the preceeding plus nitric acid and all pertinent meteorological parameters required for dispersion model predictions of downwind concentrations. All data were collected during a three week period in late January and early February, 1981.

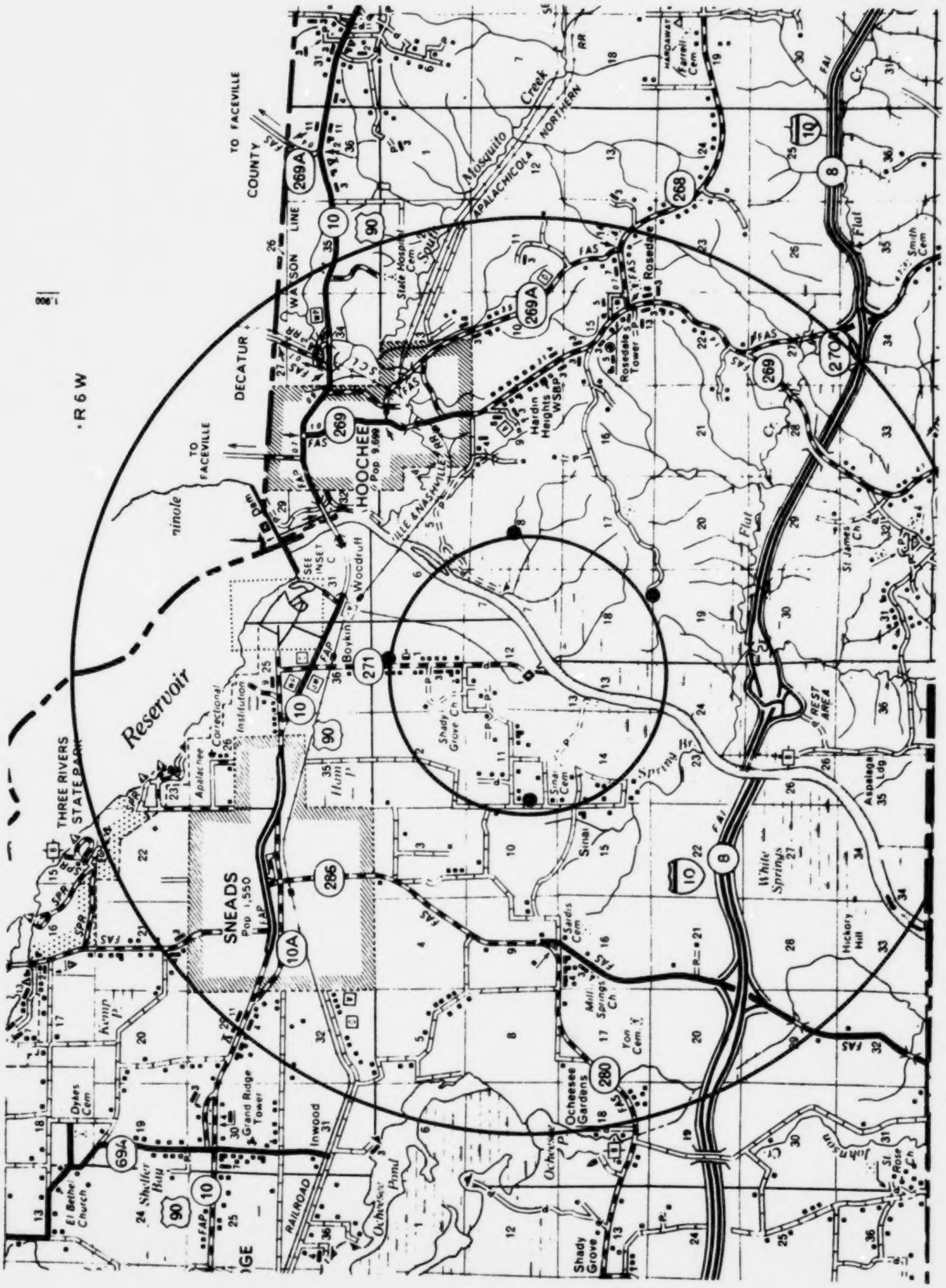
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Figure 2. Map of the vicinity of plant Scholz showing circles of radii 1½ miles and 6 miles with the approximate locations of the permanent ambient samplers at the 1½ mile radii.

SECTION 5

SOURCE EMISSION MEASUREMENT METHODS

PARTICULATE EMISSIONS

Five types of particulate sampling were carried out on the source during the test program. These included the measurement of total particulate emissions; particle size distribution measurements in both the sub-micron and super-micron portions of the particle size spectrum; sampling to quantify the emissions of condensible components; and the acquisition of samples for elemental analysis by particle size. All source samples were taken from the exit breechings of the ESPs on each unit, with the exception of a few taken at the pilot-plant scrubber exit.

Total particulate loadings were measured with a modification of EPA Method 17.[28] The modification was one intended to minimize the inclusion of H_2SO_4 in the sample. The samples were collected on quartz filter media in a heated filter holder. The sample was passed through a short (20 cm) heated tube located between the sampling nozzle and the filter holder before reaching the filter. The temperatures of the tube and filter holder were controlled to hold the gas temperature at the filter exit to 285°C (550°F) in order to minimize retention of any condensed sulfuric acid with the particulate sample. The samples obtained with modified Method 17 were later analyzed for soluble sulfate to determine the fraction of the particulate matter that was in the form of non-acid sulfate at stack conditions. The sulfate determinations were made by aqueous extraction and ion chromatography.

Cascade impactors[29-40] were used to determine particle size distributions over the aerodynamic particle diameter range from about 0.5 to 20 μm. Samples obtained with the impactors were also used to obtain measures of the sulfate fraction of the particulate matter by particle size. Again, this was done using solvent extraction and ion chromatography on the separate impaction stage catches. Stainless steel substrates coated with amorphous polypropylene were used as collection surfaces in the impactors. Ghia teflon membrane filters were used as the final filters. Blank runs were made periodically to insure that no unrecognized biases occurred as a result of gas phase constituents of the sample stream reacting with the collection media.[41] In addition, time integrated samples were taken on each unit with SoRI 5 series cyclone samplers[42] to provide representative bulk samples in six size fractions from <0.3 μm to >8 μm for subsequent elemental analysis by x-ray fluorescence and neutron activation techniques.

Electrical mobility analysis and diffusional sizing techniques were used to extend the size distribution information into the sub-micron range. A Thermosystems Electrical Aerosol Analyzer (EAA) was used to obtain size distribution data over the range from 0.01 to 0.32 μm. The SoRI Sample Extraction and Conditioning[47] system was used to provide an appropriately conditioned sample to the EAA, which is essentially an ambient air sampling device. Filter samples were obtained downstream of a series of diffusion batteries to provide data on the elemental composition of the submicron portion of the aerosol size spectrum. These samples were collected ex-situ after cooling and drying of the sample stream. Cyclones were used to limit the upper end of the size range covered by the diffusion method to a value close to both the upper size limit of the EAA and the smallest cut provided by the series cyclone system.

In addition, measurements were made with the newly developed Source Dilution Sampling System.[48-50] The latter system developed for the U.S. EPA by SoRI uses dilution cooling of an extracted sample to simulate the processes that take place when the flue gases are mixed with and cooled by ambient air immediately downwind of the stack, during which time the aerosol properties can be substantially modified by condensation, etc. The final diluted sample can be collected on a filter for gravimetric and chemical analysis, or sidestreams can be split off to provide samples for other measurement devices such as the EAA.

H_2SO_4 AND GASEOUS SPECIES

Sulfuric acid determinations were made with the method described by Cheney and Homolya (C&H).[51] In this method, a flue gas sample is withdrawn through a heated quartz probe and is passed through a heated quartz filter to a temperature controlled condenser and final filter. The probe and heated filter are maintained at a high enough temperature to insure that any previously condensed sulfuric acid will be evaporated and passed to the condensation section where the bulk of the acid is removed by the condenser. Any acid which condenses and remains suspended as particles in the gas stream in the condenser is removed by the final filter and included with the condensate for analysis. After removal of the acid, the sample stream is passed through a series of peroxide bubblers to collect SO_2, permitting simultaneous measurement of both H_2SO_4 and SO_2. The collected samples are analyzed by titration with $Ba(ClO_4)_2$ using Thorin indicator.

In addition to the manual methods described above for SO_2, the plant's SO_2 monitors were used to track SO_2 concentration changes for each unit. These provided continuous emissions data over the entire test period while the manual methods provided information on only a spot basis. The SO_2 concentrations from the plant's monitors as reported here have been corrected for instrumental offsets for better agreement with the data from the manual methods.

The plant's NO_x, O_2, and H_2O monitors were used to provide the data needed for these variables. The NO_x monitor was cross checked by means of a ThermoElectron Model A10 continuous NO_x analyzer which was in turn calibrated twice daily using bottled zero and span gases. Manual methods for O_2, CO_2, and H_2O (Orsat and Method 4) provided cross checks on the data from the remaining monitors.

SECTION 6

AMBIENT MEASUREMENT METHODS

Ambient data were taken at four fixed sampling sites and two mobile sites. The fixed stations were sites maintained by Gulf Power for monitoring SO_2 and other pollutant concentrations in the near vicinity of the plant. The two mobile stations were provided by TRC and consisted of small, enclosed trailers towed by four-wheel-drive vehicles. Each mobile monitoring station was equipped with the following:

1. Air conditioning/heating system;
2. Integrated glass sampling manifold;
3. Instrument mounting capable of providing protection during transport;
4. Roof mounting for hi-volume samplers and meteorological equipment.

Electrical service was provided for each mobile station by a portable gasoline driven generator. The generators were located at least 100 feet away from the monitoring station in the downwind direction.

AIR QUALITY INSTRUMENTATION

Air quality measurements were made using "state-of-the-art" equivalent or reference method instruments. The following instruments were used in the program:

SO_2 Monitor - Meloy SA185-2A;

NO_x, NO, NO_2 Monitor - Monitor Labs 8440E;

TSP/Particle Sizing - MISCO Model 670 high volume samplers equipped with Sierra 234 cascade impactors using glass fiber substrates and filters, and Lundgren cascade impactors using polymeric coated mylar substrates and teflon membrane filters;

Sulfate/Nitrate - Misco Model 680 high volume samplers using Teflon membrane filters followed by sodium chloride impregnated filters;

Sulfuric Acid - SoRI designed ambient sulfuric acid sampling system.[52]

The Meloy SA-185-2A uses the Flame Photometric Detection technique. Ambient air is drawn through an H_2S scrubber into the detector block and passes through a hydrogen rich flame. The intensity of light emitted by the sulfur species is measured by a photo-multiplier tube which produces a current output. The output is stabilized, linearized, and converted to a voltage proportional to the SO_2 concentration in the sample stream.

The ML 8440 analyzer uses a chemiluminescent technique for measurment of NO and a low temperature NO_2 to NO converter for NO_2 measurements. This analyzer, since it is a dual channel instrument, provides simultaneous detection of both NO and NO_x and thus eliminates the potential of skew error in the data.

The SO_2 and NO_x analyzers were calibrated daily using gas dilution systems. SO_2 and NO, contained in aluminum cylinders, were diluted to concentrations within the dynamic range of the instruments to measure data precision and validate accuracy. In addition, gas phase titration of NO was utilized to validate NO_2 data. Pollutant-free air was generated within the calibrator in an enclosed system that incorporates an ultra-violet light source and a charcoal scrubber.

Total suspended particulate samples were collected using the Misco 680 hi-volume samplers equipped with Sierra Model 234 cascade impactors. Each sampler was equipped with a flow controller to maintain a constant 40 cfm flow rate regardless of filter loading. They were also equipped with elapsed time meters to permit accurate determination of the total gas volumes sampled. Similar samplers without the Sierra impactors were used to obtain samples for sulfate, nitric acid, and nitrate analysis. Conventional glass-fiber filter media were used in the impactor equipped samplers; these were analyzed gravimetrically to determine TSP concentrations.

Teflon membrane filters were used in sampling for sulfate nitric acid and nitrates in order to minimize artifact formation. A sodium chloride impregnated filter was installed downstream of the teflon filter for the nitric acid determination.[53-58] After sampling, the filters were removed from the samplers and stored in protective containers for subsequent analysis. The sulfate analyses were made using ion chromatography on aqueous extractions from the filters.[54] The nitrate and nitric acid determinations were made with a Technicon Auto Analyzer in which the collected nitrates are diazotized and reacted with a Greiss agent to form an azo-dye which is determined spectrophotometrically. Segments of the teflon hi-vol filters were also submitted for x-ray fluorescence and neutron activation analyses to determine elemental compositions of the deposited particulate matter for use in apportioning the material found on the filters among the various possible sources.

Lundgren impactors[59] were used to collect samples for the determination of elemental concentrations by particle size. These samplers used slot type impaction nozzles and rotating drum collectors. The original design of the impactors used a slow rotation of the drum to provide a time resolved trace of the airborne particles.[59] However, for our application the drums were rotated at 1 rpm in order to obtain uniform deposition over the collection surface as is needed for x-ray fluorescence analysis. A 0.5 mil mylar film coated with Hercules Afax 800 amorphous polypropylene was wrapped around the rotating drum as a collection substrate. The polypropylene is quite sticky at ambient temperatures and thus served to insure good retention of the impacted particles.

The SoRI designed sulfuric acid samplers[52] consisted of a diffusion dryer to reduce the moisture content of the sample stream, a cyclone to strip out particles larger than about 3 μm, a diffusion denuder for the removal of SO_2 and other acid vapors, and a diffusion denuder for removal of basic vapors - especially ammonia. These components were followed by a temperature controlled, teflon lined, heating section in which any condensed sulfuric acid is evaporated. Particulate matter is then removed by a teflon filter which passes the bulk of the acid vapor to a second teflon filter that was impregnated with KOH. The latter binds the acid vapor that is passed to it. The filters are extracted separately and sulfate concentrations are determined for particulate and acid phase sulfate by ion chromatography of the two filter extracts.

METEOROLOGICAL INSTRUMENTATION

Meteorological data were collected routinely during each test period. Data collected to identify dispersion characteristics were taken from a 60 m (200 ft) meteorological tower maintained by Gulf Power Company. These data included:

1. wind speed at 60 m
2. wind direction at 60 m
3. temperature at 60 m
4. temperature difference between 10 m (30 ft) and 60 m (200 ft).

Upper air measurements were made using pilot balloons and temperature sonde equipment. A standard mercury thermometer and a Bendix aspirated psychron system were used to obtain ambient temperature, dew point temperature, and relative humidity at the pilot balloon launch site. Upper level wind speed, wind direction, and balloon ascent rate were determined by tracking the pilot balloons with two theodolites. Balloon positions were recorded every minute to yield wind velocity and instrument height data. The temperature sonde recordings were then used to determine mixing depths.

SECTION 7

PLANT EMISSION CHARACTERIZATION

BOILER OPERATIONS

Hourly average unit loads, steam flows, and coal feed rates were logged for each boiler throughout the test period. Unseasonably warm weather during the first week on site resulted in relatively low system power demands. Consequently, during the first week of testing the unit loads averaged about 60 percent of capacity. (Loads on both units dropped to about 40 percent of capacity at night and fluctuated between 60 and 100 percent during the daylight hours.) Over the following two weeks, during which the bulk of the data was taken, peak loads were maintained throughout the daylight hours (when all the ambient sampling took place) and were reduced only occasionally at night. A plot of hourly average unit loads over the entire test period is given in Figure 3. No testing was done on weekends, so data for weekday operations only are shown in the figure.

The plant provided daily analyses of the moisture, sulfur, ash, and heating values for the coal fired in each unit. These analyses were made on 24 hour composite samples. The daily analyses supplied by the plant were supplemented with Ultimate and Proximate analyses performed by a commercial testing laboratory on selected 24 hour composite samples. Average values, on an as- fired basis, for ash content, sulfur, and heating value were respectively 12.7%, 3.23%, and 12,250 BTU/lb for Unit 1, and 12.4%, 3.06%, and 12,300 BTU/lb for Unit 2. The coal moisture content averaged 4.5% for both units. The sulfur contents ranged from a low of 2.5% to a high of 3.9% over the three week test period. Table 1 gives the results of the ultimate and proximate coal analyses. As can be seen from the tables, the variations in coal properties for the two units tended to track one another, but were not identical on a day to day basis. The short term (i.e., hourly) variability was probably greater than the daily variability reflected in the table. The results of mineral analyses of the coal using EDXRF and NAA methods are given in Table 2.

Fuel usage rates are given in Table 3 together with information on the particulate emissions associated with each unit. The latter includes mass concentrations, mass median particle diameters and indicators of the instances when signifi-

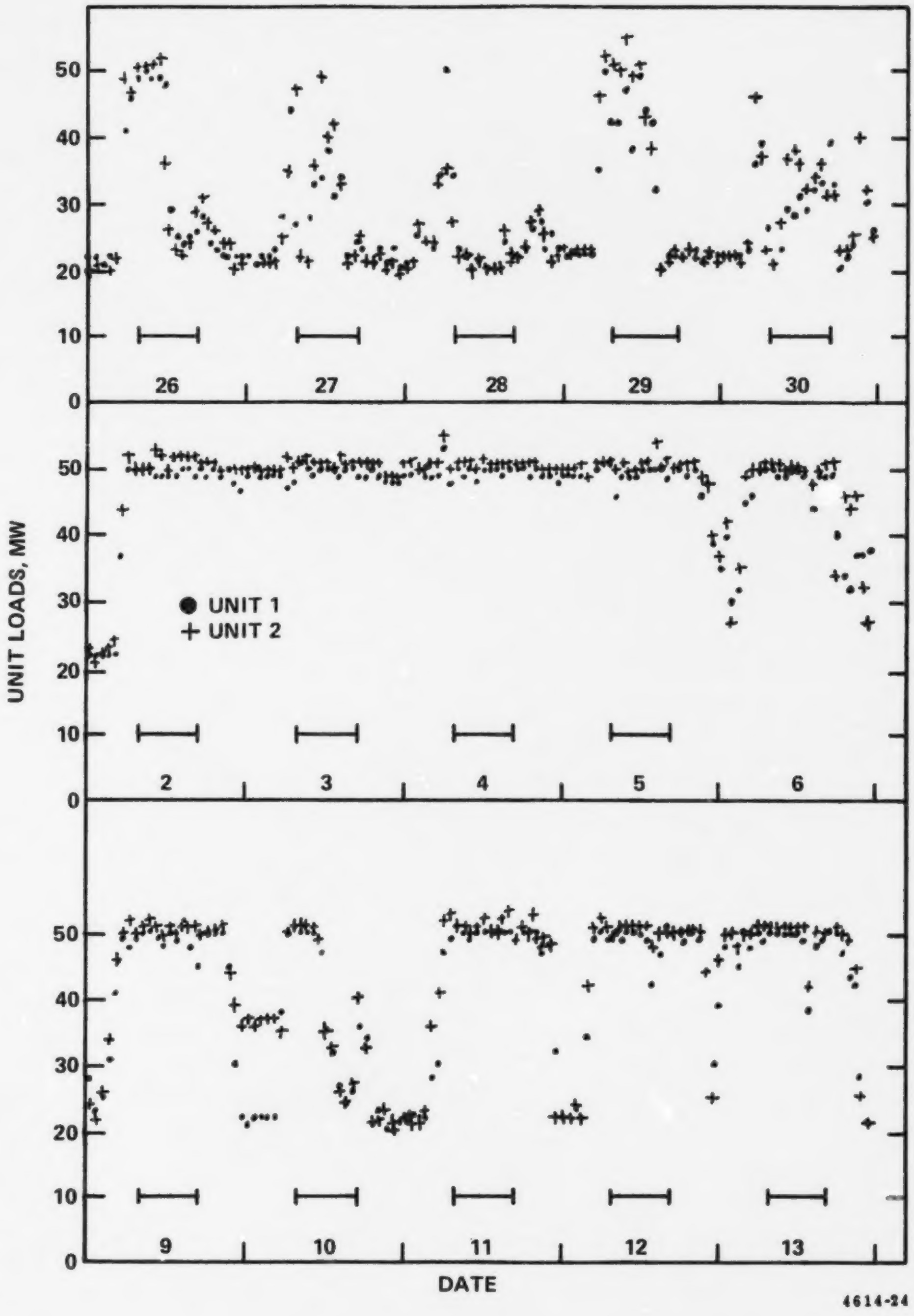


Figure 3. Hourly average unit loads through test period. (1/26/81 through 2/13/81)

TABLE 1. ULTIMATE AND PROXIMATE ANALYSES

UNIT 1

DATE	BTU/LB		%S		%ASH		%H20		% VOL ORG.	% FIXED CARBON	%H	%N	%C	%CL	%O
	PLANT	COMM.	PLANT	COMM.	PLANT	COMM.	PLANT	COMM							
1/26	12400		3.09		11.10		5.13								
1/27	12200		2.95		12.30		5.42								
1/28	12200		3.44		11.40		5.85								
1/29	12200		3.33		11.80		5.62								
1/30	12700	12100	3.70	3.72	12.30	13.20	6.12	4.28	33.90	48.50	4.69	1.20	66.74	0.13	5.99
2/2	12700	12100	3.35	3.42	11.60	13.60	4.98	4.58	33.10	48.60	4.60	1.17	53.75	0.13	18.71
2/3	12000		2.97		12.10		6.94								
2/4	12200	12400	2.48	3.00	11.70	11.40	6.05	3.47	33.60	51.50	4.89	1.17	69.14	0.05	6.86
2/5	12200		2.79	2.78	11.80	11.60	6.36	4.64	32.70	51.10	4.50	1.05	68.94	0.11	6.39
2/6	12100	12400	2.97		12.00		6.75								
2/9		12200		3.14		13.00		4.59	32.30	50.10	4.61	1.28	66.84	0.13	6.43
2/10	12000	12400	3.43	3.15	12.20	12.50	5.92	5.14	31.50	50.80	4.56	1.18	68.46	0.07	4.94
2/11	12000	12200	3.43	3.40	13.00	13.40	6.16	3.79	33.70	49.20	4.69	1.17	67.47	0.11	6.03
2/12	11900	12200	2.95	3.24	12.20	12.80	7.41	4.30	32.60	50.30	4.60	1.17	67.75	0.11	5.94
2/13	12100		3.90		12.70		5.82								
2/14	12200		3.94		12.50		6.23								

UNIT 2

DATE	BTU/LB		%S		%ASH		%H20		% VOL ORG.	% FIXED CARBON	%H	%N	%C	%CL	%O
	PLANT	COMM.	PLANT	COMM.	PLANT	COMM.	PLANT	COMM							
1/26	12100		3.21		12.20		5.71								
1/27	12100	12400	3.08	3.01	12.30	12.50	5.49	3.97	33.50	50.10	4.73	1.21	67.27	0.12	7.24
1/28	12400		3.46		11.10		5.73								
1/29	12100		3.43		11.80		4.51								
1/30	12100		3.69		12.10		5.63								
2/2	12300	12400	3.36	3.17	11.60	11.90	5.04	4.08	34.40	49.70	4.86	1.36	68.92	0.11	5.62
2/3	12000		3.03		11.60		6.96								
2/4	12200	12400	2.79	2.76	11.40	11.90	5.98	4.73	32.20	51.20	4.71	1.26	68.57	0.11	5.98
2/5	12300	12300	2.76	2.85	11.40	12.20	6.01	5.21	31.40	51.20	4.53	1.14	68.39	0.15	5.54
2/6	12100		2.96		11.70		7.12								
2/9		12200		2.93		12.50		4.58	32.30	50.60	4.68	1.23	68.11	0.11	5.84
2/10	12100	12200	3.37	3.21	12.30	13.10	6.01	4.33	32.80	49.20	4.59	1.31	67.94	0.13	5.34
2/11	12000	12200	3.50	3.38	12.80	12.80	5.99	4.53	32.60	50.00	4.47	1.14	67.73	0.14	5.67
2/12	12000	12300	2.96	3.21	12.20	12.30	7.31	5.41	31.40	50.90	4.65	1.28	67.84	0.15	5.17
2/13	12000		3.56		12.60		6.50								
2/14	12000		3.56		12.20		6.35								

TABLE 2. X-RAY FLUORESCENCE AND NEUTRON ACTIVATION ANALYSES OF COAL

		COAL	UNIT#1		COAL	UNIT#2	
		NAA	XRAY	XRAY	NAA	XRAY	XRAY
ALUMINUM (AL)	1	13336.970	8200.000	8400.000	13300.000	11600.000	11000.000
SILICON (SI)	2		13600.000	14300.000		16100.000	19000.000
PHOSPHORUS (P)	3		0.000	0.000		400.000	400.000
SULFUR (S)	4		13700.000	14500.000		13000.000	12200.000
CHLORINE (CL)	5	661.200	440.000	491.000	836.560	1156.000	1355.000
POTASSIUM (K)	6	0.000	1600.000	1600.000	5945.000	1700.000	1900.000
CALCIUM (CA)	7	0.000	300.000	300.000	2953.000	300.000	200.000
TITANIUM (TI)	8	672.510	400.000	400.000	624.880	400.000	400.000
VANADIUM (V)	9	53.010	40.000	44.000	42.690	36.000	41.000
CHROMIUM (CR)	10	2.830	0.000	0.000	17.650	0.000	0.000
MANGANESE (MN)	11	19.010	400.000	500.000	2816.190	300.000	0.000
IRON (FE)	12	38789.000	15800.000	16600.000	17687.000	11000.000	10200.000
COBALT (CO)	13	13.960	300.000	400.000	7.240	300.000	0.000
NICKEL (NI)	14	0.000	0.000	0.000	15.370	0.000	0.000
COPPER (CU)	15	2.020	0.000	0.000	0.000	0.000	0.000
ZINC (ZN)	16		0.000	0.000		100.000	100.000
GALLIUM (GA)	17		0.000	0.000		0.000	0.000
GERMANIUM (GE)	18		0.000	0.000		0.000	0.000
ARSENIC (AS)	19	442.830	0.000	0.000	73.590	0.000	0.000
SELENIUM (SE)	20	3.770	0.000	0.000	2.150	0.000	0.000
BROMINE (BR)	21	12.670	0.000	0.000	12.300	0.000	0.000
RUBIDIUM (RB)	22	19.580	0.000	0.000	22.520	0.000	0.000
STRONTIUM (SR)	23		85.000	110.000		120.000	0.000
ZIRCONIUM (ZR)	24		0.000	0.000		85.000	0.000
LEAD (PB)	25		0.000	0.000		0.000	0.000
MERCURY (HG)	26		0.000	0.000		0.000	0.000
TUNGSTEN (W)	27		0.000	0.000		0.000	0.000
CADMIUM (CD)	28	28.160	0.000	0.000	18.800	0.000	0.000
TIN (SN)	29	0.000	0.000	0.000		0.000	0.000
ANTIMONY (SB)	30	6.800	0.000	0.000	3.980	0.000	0.000
BARIUM (BA)	31	145.020	0.000	400.000	203.580	500.000	400.000
IODINE (I)	32						
MAGNESIUM (MG)	33	965.870			884.120		
SODIUM (NA)	34	489.040			236.630		
SAMARIUM (SM)	35	0.210			1.540		
CERIUM (CE)	36	25.480			17.860		
URANIUM (U)	37	1.760			1.400		
THORIUM (TH)	38	2.250			2.320		
LANTHANUM (LA)	39	11.280			8.840		
GOLD (AU)	40						
SILVER (AG)	41						
SCANDIUM (SC)	42	6.530			4.720		
EUROPIUM (EU)	43	0.360			0.320		
CESIUM (CS)	44						
MOLYBDENUM (MO)	45	0.000			2.720		
LUTETIUM (LU)	46	0.130			0.150		
TELLURIUM (TE)	47						
YTTERBIUM (YB)	48	0.890			0.740		
HAFNIUM (HF)	49	0.880			0.820		
TERBIUM (TB)	50	0.100			0.170		

UNITS ARE PPM OR MICROGRAMS ELEMENT / GRAM MATRIX

TABLE 3. UNIT LOADS AND COAL USE RATES FOR 1/1 THROUGH 1/13

		UNIT 1						UNIT 2					
DATE	TIME	UNIT LOAD MW	COAL RATE MLB/HR	COAL RATE MLB/MW	MASS MEDIAN DIA. UM	PART. CONC. MG/M3	FINE, COARSE CARBON	UNIT LOAD MW	COAL RATE MLB/HR	COAL RATE MLB/MW	MASS MEDIAN DIA. UM	PART. CONC. MG/M3	FINE, COARSE CARBON
2/2	0800	50.00	44.40	0.89				50.00	47.40	0.95			
	0900	50.00	44.40	0.89		24.50		50.00	46.10	0.92			
	1000	49.00	45.30	0.92				53.00	47.70	0.90			
	1100	49.00	42.90	0.88				52.00	47.40	0.91			
	1200	49.00	43.50	0.89	11.10	17.10	-,-	50.00	46.20	0.92	11.10	49.70	-,M
	1300	49.00	42.60	0.87				52.00	45.60	0.88			
	1400	50.00	43.00	0.88				52.00	46.20	0.89		40.20	
	1500	50.00	43.20	0.86				52.00	47.40	0.91			
	1600	49.00	43.00	0.89				51.00	45.30	0.89			
2/3	0800	51.00	43.50	0.85				51.00	45.30	0.89			
	0900	50.00	44.10	0.88				52.00	46.20	0.89	11.10	67.40	-,M
	1000	49.00	44.10	0.90	10.30	22.20	-,-	51.00	44.40	0.87			
	1100	50.00	45.00	0.90				51.00	47.70	0.94			
	1200	50.00	44.40	0.89				51.00	46.20	0.91		40.20	
	1300	50.00	44.10	0.88				50.00	46.20	0.92			
	1400	49.00	44.40	0.91				52.00	46.50	0.89	9.00	40.90	-,-
	1500	50.00	42.30	0.85	9.00	22.60	-,-	51.00	46.20	0.91			
	1600	50.00	44.10	0.88				51.00	46.00	0.92			
2/4	0800	50.00	45.00	0.90				51.00	48.30	0.95			
	0900	49.00	44.10	0.90		67.00		51.00	46.20	0.91			
	1000	50.00	43.50	0.87	13.10	59.60	S,M	51.00	44.70	0.88	11.40	62.70	-,M
	1100	48.00	43.50	0.91				50.00	45.60	0.91			
	1200	51.00	45.30	0.89				52.00	48.30	0.93			
	1300	50.00	43.50	0.87				51.00	42.30	0.83		55.70	
	1400	50.00	42.90	0.86				51.00	45.00	0.88			
	1500	49.00	44.10	0.90	8.03	22.20	S,M	51.00	45.60	0.89	10.40	47.50	-,S
	1600	50.00	43.00	0.88				51.00	45.30	0.89			
2/5	0800	46.00	42.30	0.92				50.00	47.70	0.95			
	0900	49.00	39.90	0.81				51.00	43.00	0.86			
	1000	49.00	43.00	0.89	6.09	22.10	-,-	50.00	45.90	0.92			
	1100	49.00	40.80	0.83				50.00	45.90	0.92	10.90	42.60	-,M
	1200	50.00	47.80	0.96				51.00	45.60	0.89			
	1300	50.00	44.10	0.88				51.00	47.10	0.92			
	1400	50.00	43.20	0.86				54.00	45.60	0.84			
	1500	50.00	44.10	0.88	5.91	18.60	-,-	51.00	45.90	0.90	11.40	50.50	-,M
	1600	49.00	43.50	0.89				50.00	45.60	0.91			
2/9	0800	50.00	44.40	0.89				51.00	47.40	0.93			
	0900	50.00	44.40	0.89				52.00	46.10	0.89			
	1000	49.00	44.40	0.91				51.00	47.70	0.94			
	1100	48.00	44.70	0.93				50.00	47.40	0.95			
	1200	50.00	44.10	0.88				51.00	46.20	0.91			
	1300	49.00	45.00	0.92				50.00	45.60	0.91			
	1400	52.00	43.20	0.83				51.00	46.20	0.91			
	1500	48.00	44.10	0.92	5.55	22.30	-,-	51.00	47.40	0.93	17.00	64.00	M,M
	1600	45.00	44.70	0.99				51.00	45.30	0.89			
2/10	0800	50.00	43.00	0.86				51.00	46.00	0.90			
	0900	50.00	43.50	0.87				51.00	46.20	0.91			
	1000	50.00	45.00	0.90	6.70	21.00	S,-	51.00	50.70	0.99	19.30	254.00	M,M
	1100	47.00	40.80	0.87				49.00	43.20	0.88			
	1200	35.00	28.50	0.81				35.00	27.90	0.80			
	1300	32.00	31.50	0.98				33.00	33.00	1.00			
	1400	27.00	23.70	0.88				26.00	22.20	0.85			
	1500	24.00	20.10	0.84				24.00	26.70	1.11			
	1600	26.00	25.80	0.99				27.00	27.90	1.03			
2/11	0800	51.00	45.30	0.89				51.00	47.10	0.92			
	0900	50.00	45.90	0.92				51.00	47.40	0.93			
	1000	49.00	45.60	0.93				50.00	47.10	0.94			
	1100	50.00	45.90	0.92				51.00	47.10	0.92			
	1200	50.00	46.50	0.93				52.00	48.60	0.93	9.36	21.60	M,M
	1300	50.00	48.00	0.96				50.00	48.60	0.97			
	1400	50.00	44.40	0.89	8.67	46.00	-,-	50.00	46.80	0.94			
	1500	50.00	45.90	0.92				52.00	48.30	0.93			
	1600	50.00	47.50	0.95				53.00	49.50	0.93			
2/12	0800	50.00	47.40	0.95				50.00	48.30	0.97			
	0900	49.00	46.20	0.94				51.00	48.30	0.95			
	1000	50.00	46.50	0.93	3.50	12.40	-,-	51.00	47.10	0.92			
	1100	50.00	45.90	0.92				51.00	48.60	0.95			
	1200	50.00	46.50	0.93				51.00	48.90	0.96			
	1300	49.00	44.70	0.91				51.00	48.30	0.95			
	1400	42.00	37.50	0.89				48.00	37.80	0.79			
	1500	47.00	43.20	0.92				50.00	47.40	0.95	7.67	38.30	S,S
	1600	51.00	45.60	0.89				50.00	48.30	0.97			
2/13	0800	50.00	45.30	0.91				51.00	48.00	0.94			
	0900	50.00	45.60	0.91				51.00	47.40	0.93			
	1000	50.00	45.60	0.91				51.00	47.70	0.94			
	1100	50.00	46.20	0.92				51.00	47.10	0.92			
	1200	50.00	44.90	0.90				51.00	47.40	0.93	3.96	12.30	-,-
	1300	49.00	45.30	0.92				51.00	48.00	0.94			
	1400	38.00	36.90	0.97				42.00	37.50	0.89			
	1500	48.00	45.00	0.94	8.20	31.00	S,-	50.00	47.40	0.95			
	1600	49.00	45.60	0.93				50.00	47.40	0.95			

CARBON: S=SLIGHT
M=MODERATE
H=HEAVY

cant coarse and fine carbon was present in the emissions. The carbon emissions were related to boiler upsets which occurred on several occasions. These upsets resulted in reduced combustion efficiency and significant carryover of unburned carbon (coal) to the ESP's. Upsets occurred on 2/4 and 2/11 in Unit 1 and on 2/5 and 2/9, 10, and 11 in Unit 2. These upsets were reflected in the coal usage as shown in Table 3, and resulted in greatly increased particulate loadings. The increased loadings were primarily related to the addition of large particles (dia. >100 μm), but significant soot (sub-micron carbon) was produced on occasion. The carbon carryover appears to have affected the H_2SO_4 concentrations as will be discussed later.

PARTICULATE EMISSION CONTROLS

The ESP's in service at Scholz have far larger specific collection areas (SCA's) than is typical industry practice. Although the plant is generally found to be only marginally in compliance with particulate emission codes when tested using EPA Method 5, it operates routinely with a "clear stack" (opacities <2%). Typical values for particulate loadings range from 40 to 100 mg/DNM^3 as determined by Method 5. Initial particulate tests during this program using EPA Method 17 and cascade impactors consistently showed loadings in the range of 0.02 to 1.0 mg/DNM^3. The discrepancies between the latter results and those of the Method 5 compliance tests probably result from the inclusion of sulfuric acid, which would be present as a vapor at stack conditions, in the Method 5 catch.

In order to make the plant emissions more nearly match normal industry practice, two of the four sequential fields in the ESP's were turned off. Further, the voltages in the remaining sections were reduced to obtain operating currents that were 25% of the normal values used in those sections. Under these operating conditions the outlet opacities, as indicated by the plant's opacity monitors, ranged from about 3 to 10 percent, depending on unit load, ESP rapping, etc. These opacities were still rather low compared to normal industry practice for coal fired plants. With the revised ESP operating conditions, the "instack" particulate concentrations were in the range of 20 to 40 mg/DNM^3. Even higher concentrations were measured on a few occasions when pulverizer problems occurred and large quantities of unburned coal were carried out of the boilers.

SOURCE TESTS

An overview of the source emission parameters is given in Table 4. This table summarizes all emission rate measurements for the principal components of interest - particulates, SO_2, H_2SO_4, and NO_x - for each unit. The CEA pilot plant scrubber,

TABLE 4. SUMMARY OF EMISSIONS MEASUREMENTS

		UNIT 1							UNIT 2							SCRUBBER
DATE		GAS FLOW M3/S	TEMP DEG.C	UNIT LOAD MW	PART CONC MG/ DNM3	H2SO4 CONC PPM	SO2 CONC PPM	NOX CONC PPM	GAS FLOW M3/S	TEMP DEG.C	UNIT LOAD MW	PART CONC MG/ DNM3	H2SO4 CONC PPM	SO2 CONC PPM	NOX CONC PPM	GAS FLOW M3/S
1/26	A	99	152	50					99		46					0
	P	71		25					64	159	20		4.50	1315		36
1/27	A	71		30	).14				71	157	35		6.60	1645		0
	P	71		25	6.00				71	143	25	1.11	3.90	1447		0
1/28	A	61		22					61	131	22		4.30	1698		0
	P	61		22	0.55				61		22					0
1/29	A	83	146	45	3.81	2.70	2200		104		50					0
	P	64	132	25	2.71	3.00	1870		61		25	41.61				0
1/30	A	66	123	30		1.40	2065		61		30	87.89				0
	P	76	133	35	70.60	2.50	2170		78		35	47.90				0
2/2	A	101	152	50	24.50			490	115	152	52		8.60	1775	530	0
	P	104	152	50	17.10	4.00	2020	500	115	154	52	45.00	11.00	1925	525	29
2/3	A	104	152	50	22.10	3.30	2120	500	110	149	51	67.30		1900	475	22
	P	101	152	50	21.60		2060	515	110	149	51	39.90	6.50	1700	475	22
2/4	A	104	149	50	63.50		1770	485	111	149	51	59.80	7.00	1690	500	33
	P	104	152	50	23.00	1.70	1770	485	111	152	51	51.50		1530	490	0
2/5	A	104	149	49	22.00	2.00	1870	510	112	146	51	42.50		1700	440	25
	P	104	149	50	16.70	1.20	1870	515	106	149	51	46.80	5.60	1690	400	18
2/6	A	104	149	50			1820	490	111	149	51			1650	460	31
	P	101	149	49			1020	425	106	149	50			2050	390	31
2/9	A	108	149	49			1835	450	110	152	51		6.00	1400	480	0
	P	110	149	50	22.20	4.60	2210	425	110	152	51	63.80		1720	500	18
2/10	A	104	146	50	20.80	1.90	1985	445	94	149	51	254.0		2050	360	28
	P	76	127	30			1005	350	78	129	30		3.40	1750	290	28
2/11	A	109	146	50			2435	475	109	143	51		3.70	2500	400	22
	P	109	152	50	46.70	4.80	2285	490	106	143	51	21.40		2425	410	15
2/12	A	109	146	50	12.30	3.00	2275	480	111	143	51			2120	430	11
	P	109	146	50			2025	480	109	141	50	38.20	6.20	2000	415	18
2/13	A	109	149	50			205	470	109	141	51		3.30	2240	400	27
	P	106	143	50	31.60		2535	450	109	143	50	12.10		2150	440	27

when in operation, reduces the SO_2 concentration in the portion of the Unit 1 effluent that it treats by approximately 90%.[60] It may also result in some reduction in the H_2SO_4 concentration. Its effect on NO_x and particulate concentrations insofar as the source-ambient relationships are concerned are minimal. The particulate concentrations are reduced by the scrubber and undergo some alterations in chemical composition. Because of the lower gas temperature and stack height, the dispersion characteristics of the scrubber effluent may not totally match those of the main stack.

Particulate Emissions

The results of the modified Method 17 sampling are presented in Table 5. The results designated by "hot filter" refer to particulate concentrations determined from heated instack filters (Temp. = 285°C) intended to collect "acid-free" particles (flyash). The values designated as "cold filter" results refer to concentrations based on the material found on an ex-situ, low temperature (70°C) filter. The latter values should be dominated by H_2SO_4 associated with the flue gas sampled during the Method 17 run. High purity quartz filters were used in all Method 17 sampling to minimize artifact sulfate formation through SO_2 reacting with the filter material.

During the course of the sampling it was found that the temperatures of the probe and hose could not be kept high enough to prevent condensation from occurring on their walls, especially at inter-connections. Sulfate concentrations obtained from washes of these components were given in Table 5. Total sulfate concentrations from the combined ex-situ filter, probe and hose were of the same general level as those determined by the Homolya and Cheney method (to be discussed later in this report) but were somewhat higher than the latter. Oxidation of SO_2 to SO_4^{-2} on the walls of the stainless steel probe and associated fittings may account for the difference. The sulfate concentrations determined solely from the ex-situ filter were consistently lower than the H&C values. Soluble sulfate determinations were made on the Method 17 instack filter catches and these results are also given in Table 5. When sulfuric acid was excluded, between 2 and 5% of the total particulate emissions were found to be soluble sulfates.

Cascade impactors were used to measure sulfate particulate emission as well. The results of the impactor measurements provided data on the sulfate concentrations by particle size rather than on a bulk basis as provided by Method 17. These samples were obtained in-situ at flue gas conditions. The sulfate contribution to the total particulate loading obtained through the impactor samples ranged from about 2 to 5%, and correlated quite well with the Method 17 results. Figure 4 illustrates the dependence of the sulfate fraction of the particulate emissions

TABLE 5. RESULTS OF SULFATE CONCENTRATIONS FROM METHOD 17 SAMPLES

			Heated In-stack Filter			Cold Backup Filter		
Run #	Date	Unit #	Total Particulate mg/DNCM	Sulfate mg/DNCM	Sulfate %	Total Particulate mg/DNCM	Sulfate mg/DNCM	Sulfate %
1	1/27/81	1	>0.14*	0.020	<14			
2	1/27/81	2	1.11	0.136	12.3			
3	1/28/81	1	0.15*	0.027	<19			
4	1/29/81	2	3.81	0.133	3.5	5.74	3.47	61
5	1/29/81	2	41.61	1.089	2.6	1.98	0.973	49
6	1/30/81	2	87.89	2.138	2.4	7.80	4.70	60
7	1/30/81	1	70.61	2.35	3.3			
8	2/2/81	1	24.48	0.833	3.4			
9	2/2/81	2	40.20	1.62	4.0	19.64	12.47	63.5
10	2/3/81	2	40.18	1.095	2.7	8.21	4.90	59.6
11	2/4/81	1	67.79	0.896	1.3	1.68	0.003	0.2
12	2/4/81	2	55.66	1.116	2.0			
14	2/13/81	CEA Scrubber	2.64	0.917	34.7			
15	2/14/81	CEA Scrubber	4.24	1.425	33.6			
16	2/14/81	CEA Scrubber	1.15	0.884	76.9			
Probe Wash Data								
4	1/29/81	2		62.56				
5	1/29/81	2		42.82				
10	2/3/81	2		35.95				

* Filter torn in unloading and some filter material was lost.

on total loading as found from the combined impactor and Method 17 data. The agreement of the two sets of values tends to indicate that the H_2SO_4 present in the flue gas was essentially all in the vapor phase, as condensed acid would have been retained in the impactors as part of the particulate catch. The H&C method H_2SO_4 data to be given later showed sulfate concentrations 10 to 15 fold greater than those associated with the flyash.

Soluble sulfate was found to increase as a percentage of particulate mass as particle sizes decreased and as a percentage of total mass as particulate concentrations decreased. Table 6 presents data on the concentrations of soluble sulfate and total mass for the Scholz emissions for three size fractions: >2 μm, 0.3 to 2 μm, and <0.3 μm. The large size fraction, which contained the bulk of the particulate emissions, was found to contain about 2 to 5% sulfate. Soluble sulfate accounted for 10 to 20% of the mass of the 0.3 to 2 μm size fraction and 15 to 35% of the <0.3 μm fraction. The greater total sulfate fractions for low particulate loadings that were shown in Figure 4 probably were related to shifts toward smaller average particle sizes at lower particulate loadings or greater ratio of $H_2SO_4(g)$/particulate mass collected.

A few runs using the newly developed Source Dilution Sampling System (SDSS) revealed a dramatic increase in the concentration of submicron particles after dilution quenching of the flue gas. This effect is illustrated in Figure 5. The concentration increase is consistent with the formation of a sulfuric acid fume. Filter samples taken from the SDSS showed particulate mass concentrations in the <2 μm size fraction that were 10 to 30 times higher than the concentrations found for the instack samples for the same size range, as shown in Table 7. The increase in mass concentration can be accounted for quantitatively by condensation of the measured H_2SO_4 in the flue gas. We can thus expect that the bulk of the direct sulfuric acid emissions from the plant will be present in the aerosol downwind of the plant as submicron particles. The SDSS results indicate that initially the acid will be found in the <0.3 μm sizes, but coagulation will result in a gradual increase in the mean size of the acid laden particles.

TABLE 6. SULFATE FRACTIONS BY PARTICLE SIZE FROM IMPACTOR SAMPLES

			Particulate Size Range								
			Dia. <0.34 μm			0.34 μm≥Dia.≤1.92 μm			Dia. >1.92 μm		
Run #	Date	Unit #	Weight (mg)	SO_4^{2-} (mg)	%SO_4^{2-}	Weight (mg)	SO_4^{2-} (mg)	%SO_4^{2-}	Weight (mg)	SO_4^{2-} (mg)	%SO_4^{2-}
2[a]	1/28/81	1	0	(3.94)	--	0.760	-0.175	--	4.48	1.44	32.1
3[a]	1/29/81	2	0	(0.096)	--	1.45	-0.030	--	2.60	-0.035	--
7[b]	1/30/81	2	5.95	2.11	35.5	15.67	3.287	21	109.82	7.646	7.0
9[b]	2/2/81	2	0	(0.17)	--	5.31	0.542	10.2	87.54	1.42	1.6
10[b]	2/2/81	1	0	(0.17)	--	2.01	0.967	48.1	31.05	3.21	10.3
13	2/3/81	2	3.01	0.88	29.2	6.59	1.89	28.7	119.07	4.22	3.5
14[c]	2/3/81	1	0.96	--	--	3.47	0.722	16.2	35.72	1.34	3.8
17[c]	2/4/81	1	1.76	--	--	6.32	0.630	10	114.44	2.60	2.3
20	2/4/81	2	2.08	0.686	33	4.83	0.642	13.3	80.96	1.75	2.2
21[c]	2/5/81	1	3.49	--	--	4.96	1.40	16.6	35.54	0.906	2.5
22	2/5/81	2	2.12	0.358	16.9	4.16	0.367	8.8	76.25	1.46	1.8
26	2/9/81	1	2.92	0.784	26.8	5.47	0.692	12.7	41.6	1.20	2.9
27	2/9/81	2	4.05	0.686	16.9	3.94	0.677	17.2	116.02	2.98	2.6
28	2/10/81	1	2.22	0.470	21.2	4.1	0.387	9.4	28.88	0.926	3.2
29	2/10/81	2	1.79	0.142	7.9	13.31	0.192	1.4	450.73	5.32	1.2
30	2/11/81	2	0.70	0.228	32.6	3.21	0.562	16.2	34.79	1.266	3.6
31	2/11/81	1	2.39	0.482	20.2	6.04	0.932	15.4	81.14	2.02	2.5
32	2/12/81	1	1.16	0.334	28.8	4.7	0.652	13.9	16.26	1.101	6.8
33	2/12/81	2	2.38	0.690	29.0	7.85	0.742	9.5	61.41	1.48	2.4
34	2/13/81	2	1.34	0.274	20.4	4.19	0.427	10.2	16.31	0.841	5.2
35	2/13/81	1	2.25	0.762	33.9	5.23	0.947	18.1	48.08	1.706	3.5
	2/13/81		Dia. <0.21 μm			0.21 μm≥Dia.≤1.39 μm			Dia. >1.39 μm		
36	2/13/81	CEA Scrubber	2.32	0.822	35.4	6.34	3.06	48.3	13.69	5.67	41.4

[a] Impactor substrates were bare stainless steel.

[b] Impactor substrates were stainless steel coated with Apiezon H grease.

[c] Combined filter (dia. <0.34 μm) with the 0.34 to 1.92 μm particulate.

Note: All other impactors were run using stainless steel substrates coated with polypropylene.

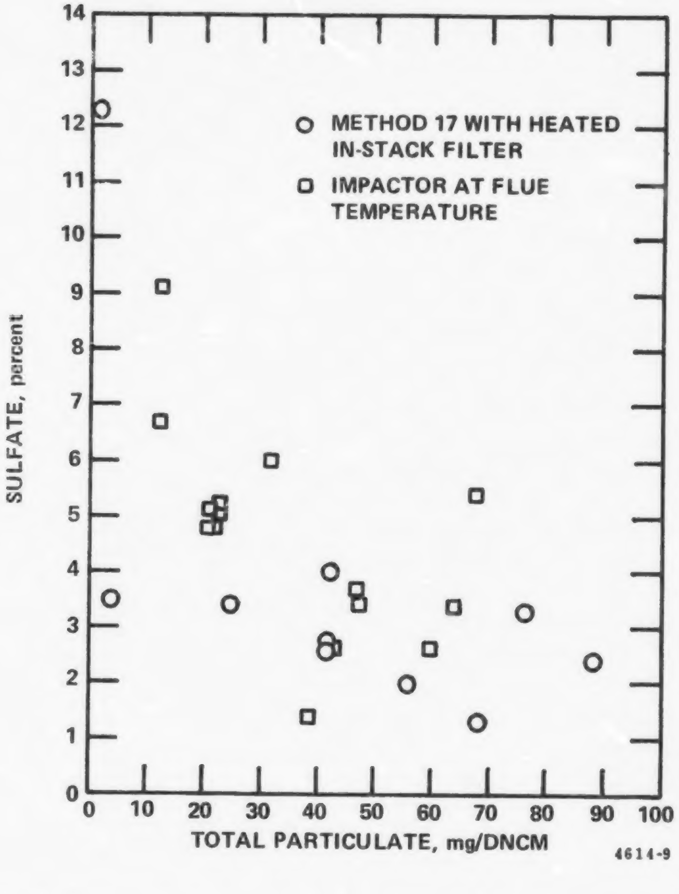


Figure 4. Percent sulfate versus total particulate concentration for the impactor and Method 17 samples.

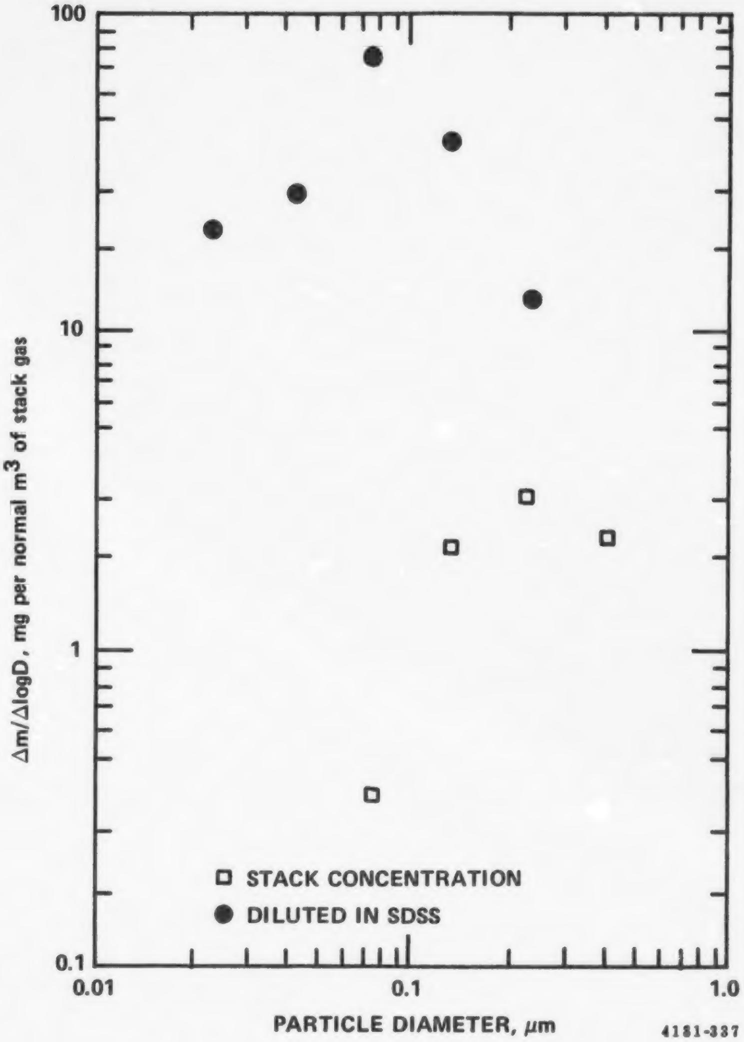


Figure 5. Submicron size distribution in stack gas from coal-fired boiler before and after dilution in Dilution Stack Sampling System. Note evidence of sulfuric acid condensation mode.

TABLE 7. COMPARISON OF PARTICULATE CONCENTRATIONS BEFORE AND AFTER DILUTION QUENCHING OF FLUE GASES

Sample		Concentration, mg/DNM^3		
		Fine (<2 μm)	Coarse >2 μm)	Total
Method 17	(2/4/81)			35.7
Impactor	(2/3/81)	2.0	21	23
Impactor	(2/4/81)	2.2	24	27
SDSS	(2/3/81)	25		
SDSS	(2/4/81)	27		

Typical particle size distributions from each of the two units are shown in Figures 6 and 7. The figures show averages for each unit and the ranges of the data for the period February 2-13. The distributions shown include data from both the impactors and the EAA. The EAA data indicated that virtually none of the aerosol mass was contained in particles smaller than 0.1 μm at stack conditions. The two techniques agreed reasonably well in terms of the mass concentration of the submicron mode, with the EAA data generally showing somewhat higher values than did the impactors, possibly the result of incomplete removal of sulfuric acid vapor prior to dilution. The EAA data indicates the presence of a narrow submicron mode with an MMD of about 0.15 to 0.2 μm - such modes are commonly found to be produced by pulverized coal boilers. Grand average size distributions for the combined units over the same period are shown in Figures 8 and 9.

The variability in the particle size distributions were caused for the most part by changes in boiler operation, particularly the upsets previously mentioned. The primary difference between the distributions for the two units lies in much higher average concentrations of large particles in the case of Unit 2 as compared to Unit 1. This difference is probably related to a difference in combustion efficiency for the two units. During the period from February 2-13, the Unit 1 firing rate averaged 895 lb/mw-hr while Unit 2 averaged 920 lb/mw-hr. (The ranges were 870 to 960 lb/mw-hr for Unit 1 and 880 to 990 for Unit 2.)

In addition to boiler problems, changes in particulate loadings and particle size distributions occurred when a problem developed in one section of one of the ESP's forcing it out of service (with another section being placed in service as a substitute). Further, on one occasion the operator mistakenly set the ESP's up with operating voltages and currents other than those needed to reproduce the desired conditions.

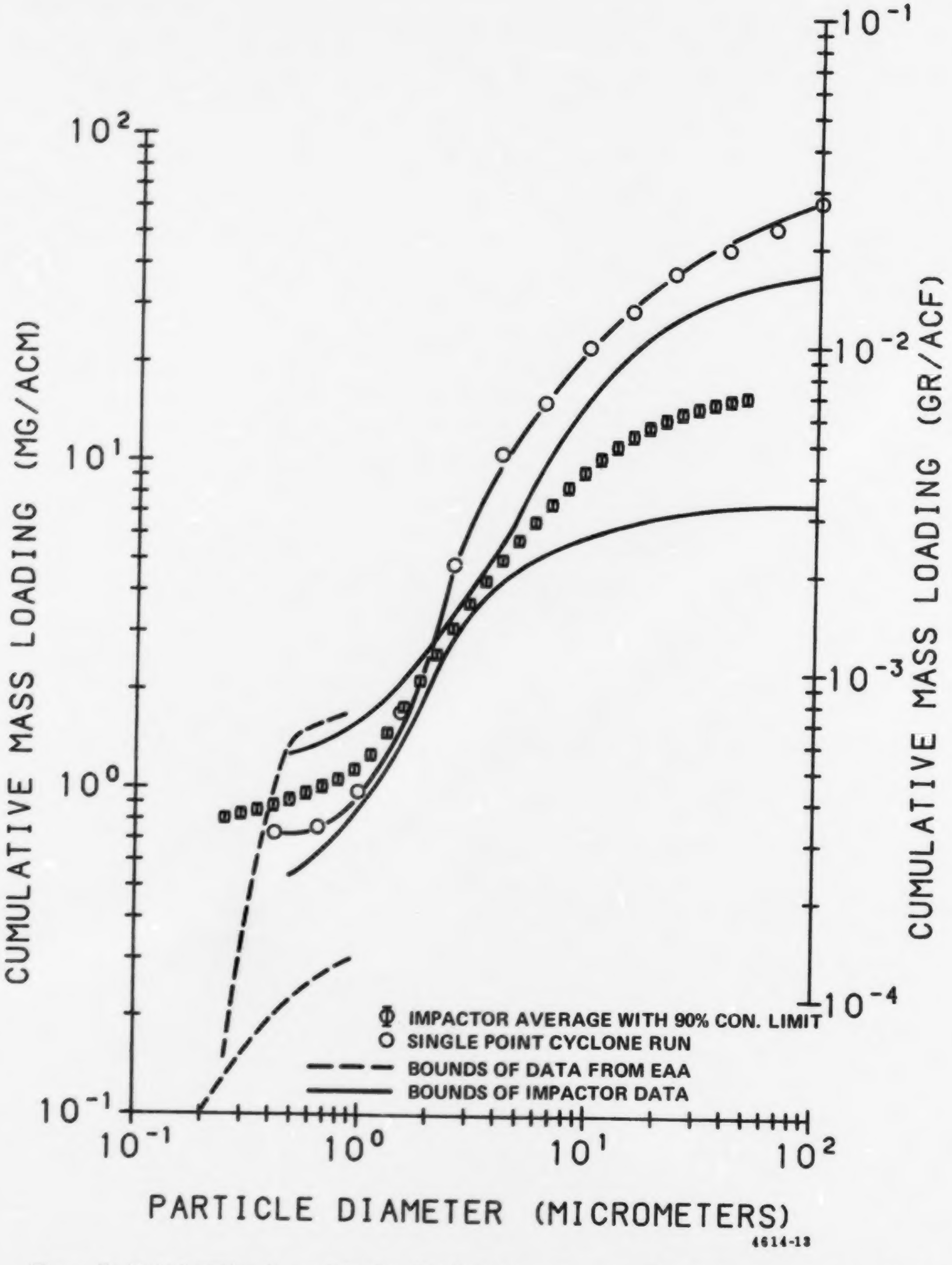


Figure 6. Unit 1 ESP exit particle size distribution on a cumulative mass concentration basis.

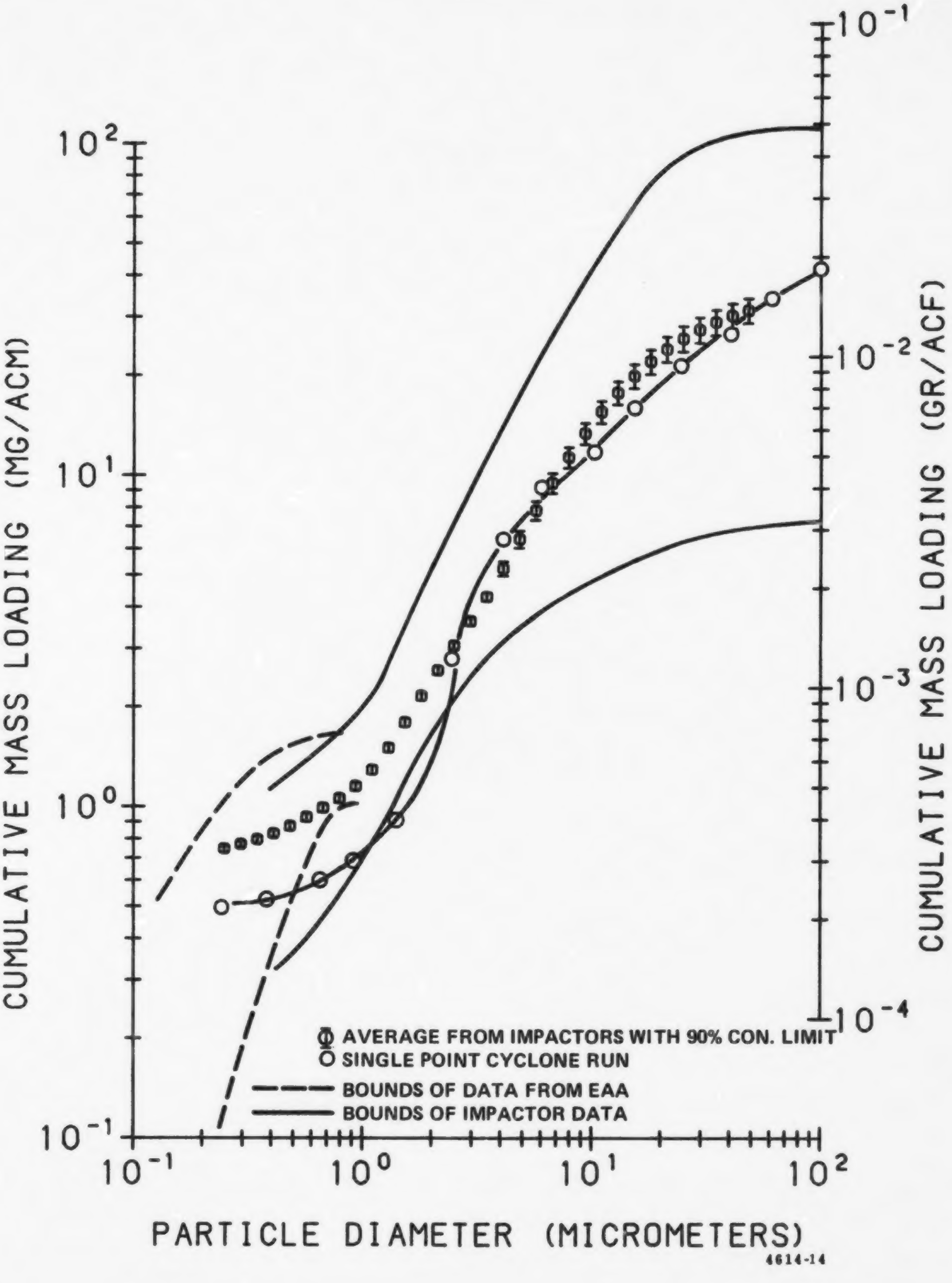


Figure 7. Unit 2 ESP exit particle size distribution on a cumulative mass concentration basis.

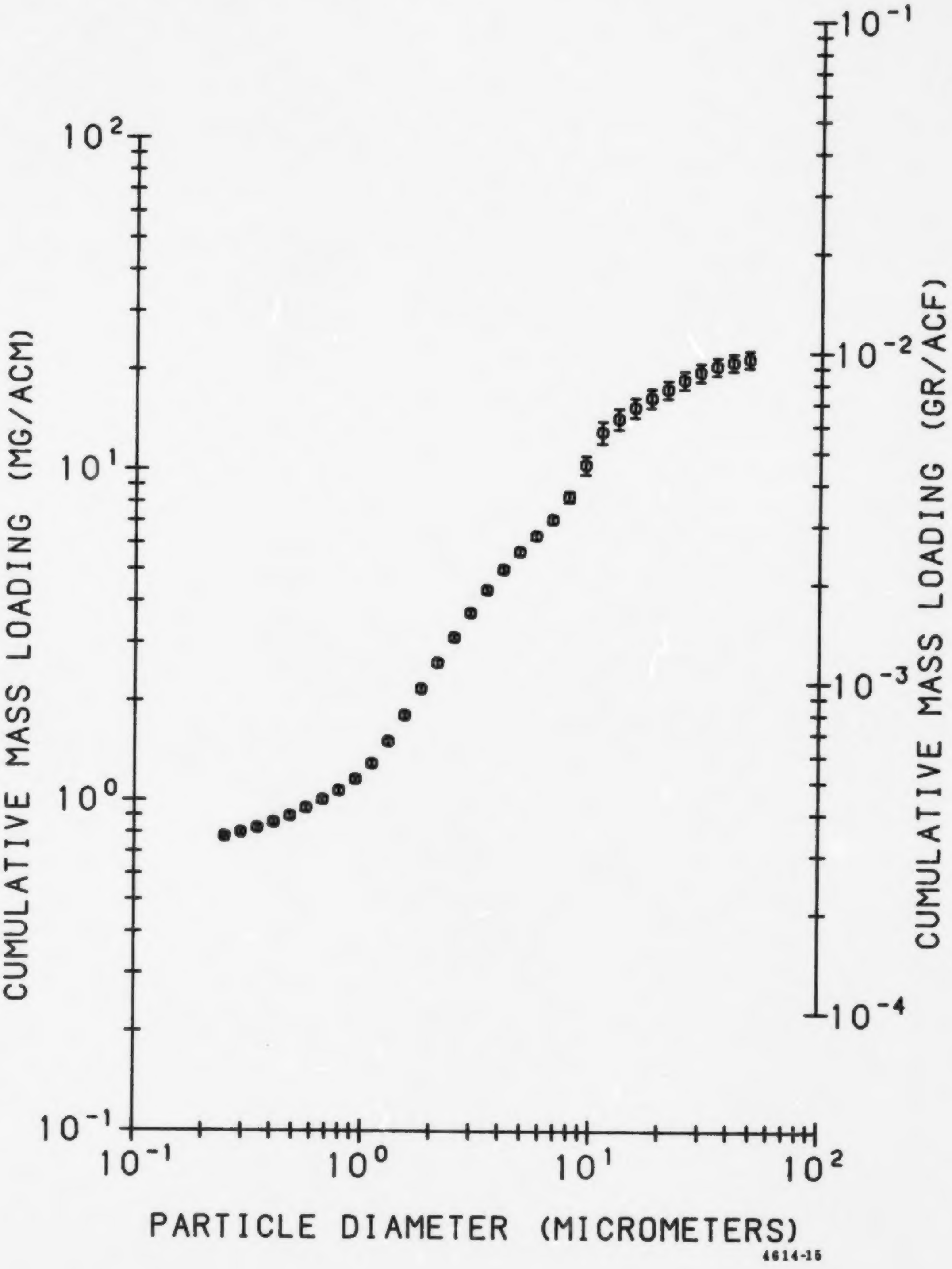


Figure 8. Grand average particle size distribution on cumulative mass concentration basis.

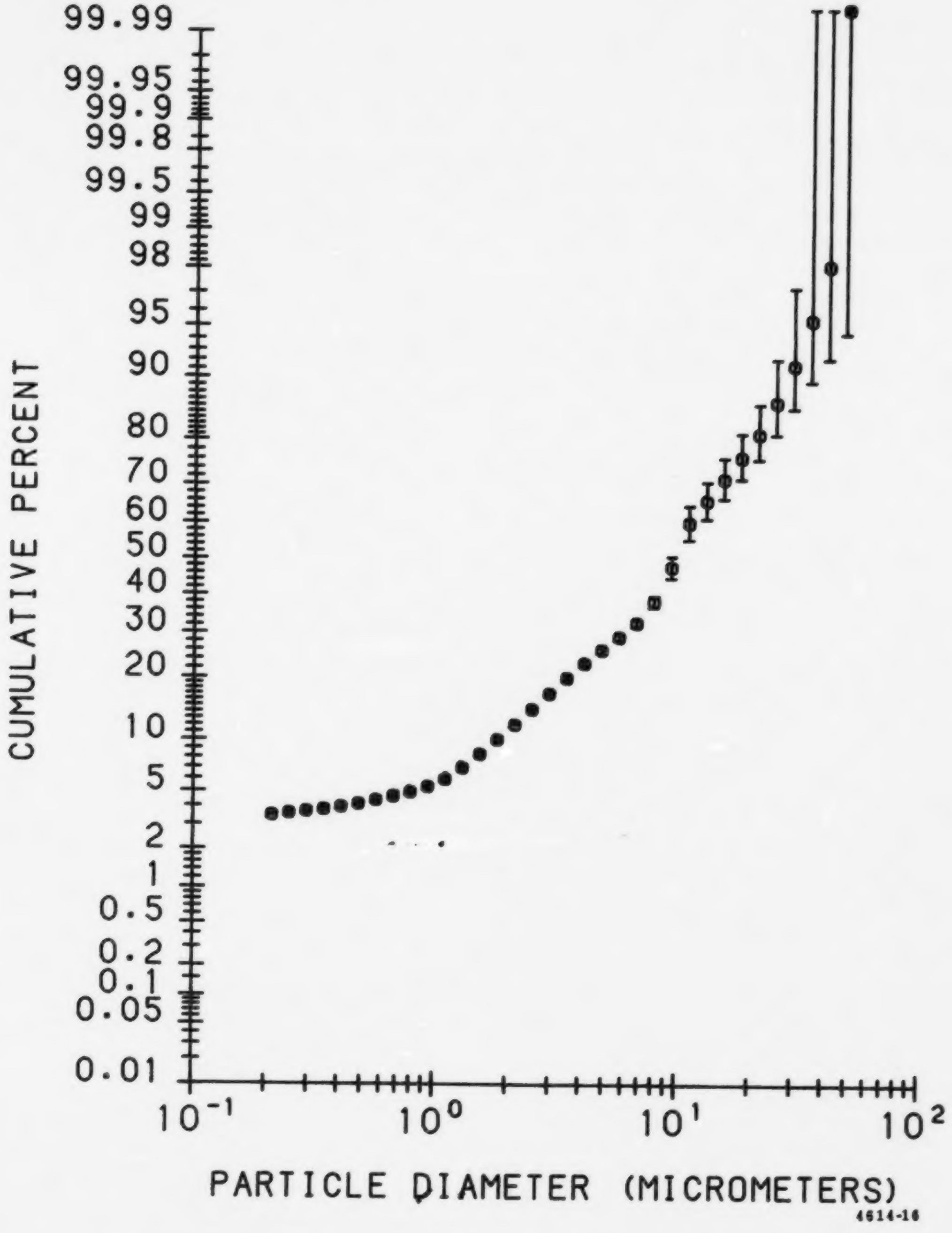


Figure 9. Grand average particle size distribution on cumulative weight percentage basis.

Typical mass median diameters were in the range of 7 to 12 µm with much larger values during periods of boiler upsets. At least two distinguishable modes were present (excluding a submicron mode) in the impactor data, one having a median diameter of about 3.5 µm and the other in the range of about 12 to 40 µm.

Size distributions for the scrubber effluent, illustrated in Figures 10 and 11, showed two strong modes, one at about 1 µm and the other at about 30 µm. The smaller mode is probably pass through particles from the inlet augmented by condensed sulfuric acid, while the clearly separated, large-particle mode is likely to have been residue particles from the scrubber liquor. For sizes smaller than 1.5 µm, the ESP and scrubber distributions are physically identical within the precision of the data. Chemically, the scrubber liquor was rich in Na, Ca, and Mg.[60] Thus entrained solids from the liquor may be an identifiable component of the plant emissions in the ambient air samples. The scrubber emissions in size range below 0.3 µm showed sulfate percentages like those at the ESP outlets. However, the coarser particles showed much higher sulfate fractions (approximately 40% versus 5%), albeit with much lower loadings than those at the ESP exits.

Elemental Composition of the Ash

In order to quantify the impact of source emissions on the downwind surroundings, a tracer or "source fingerprint" is needed. One such "fingerprint" is the relative concentrations of various elements in the particles emitted by the source. The mechanisms of particle formation in combustion sources are such that the elemental composition of the particles can and probably will depend on the size of the particles. In particular, elements which are present in more volatile forms during combustion will tend to be enriched in the smaller particle size fractions as a result of evaporation and subsequent recondensation as the flue gases pass through the combustion and heat exchange zones of the boiler. The latter processes are believed to result in the formation of the previously mentioned submicron mode in the aerosol size distribution. Moreover, some elements, notably As, Se, and Hg (as well as S) are volatile at stack conditions and condense in the plume as the gases cool. Again, the condensation will tend to result in the accumulation of these elements in the smaller particles. Thus samples taken at flue gas conditions may not properly represent the concentrations of these elements insofar as their concentrations in the downwind aerosol are concerned.

Particle deposition takes place on a size selective basis as the plume travels downwind, with larger particles being lost more rapidly. Thus the gross composition of the emitted

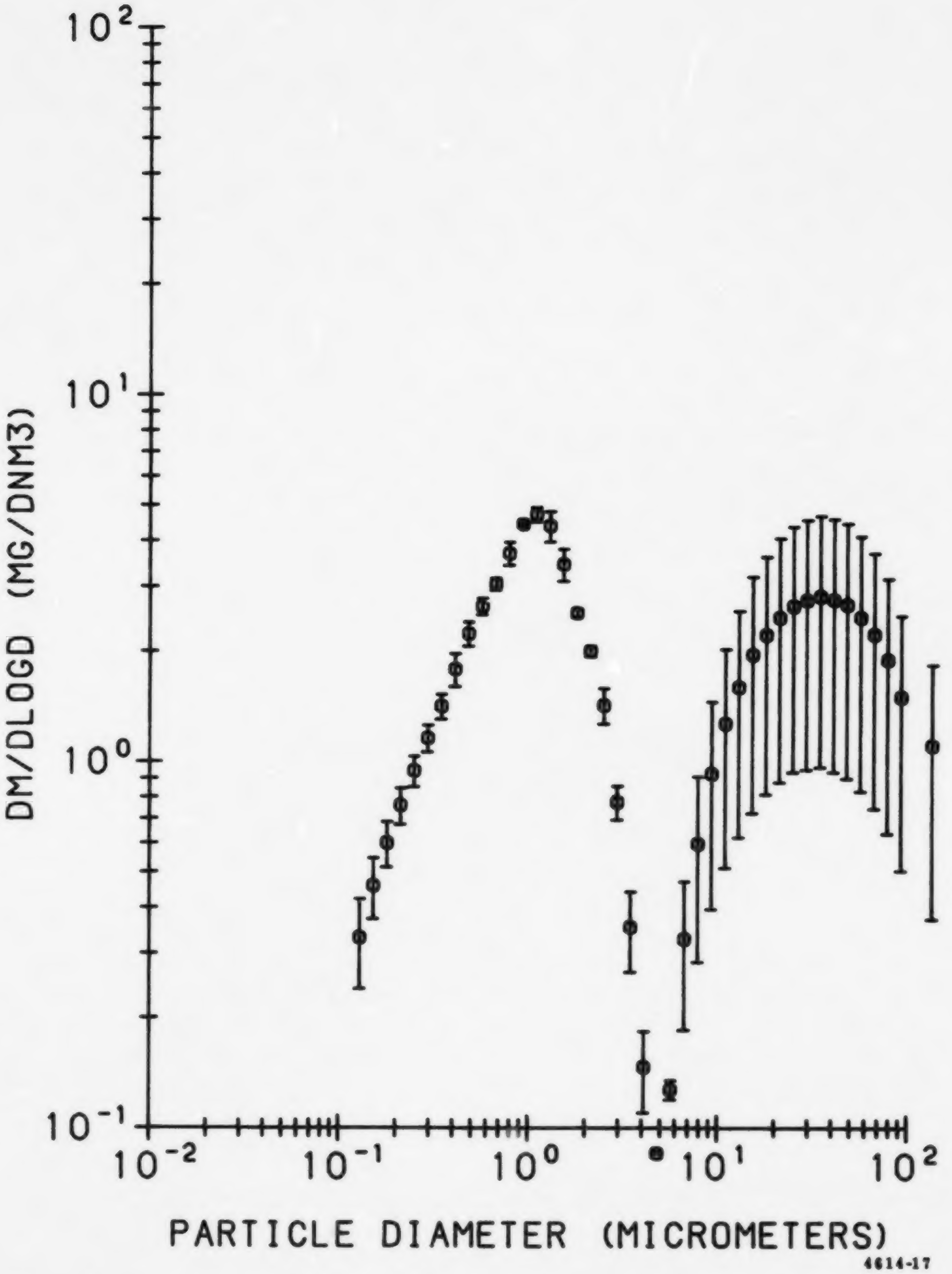


Figure 10. Scrubber size distribution on a differential mass distribution basis.

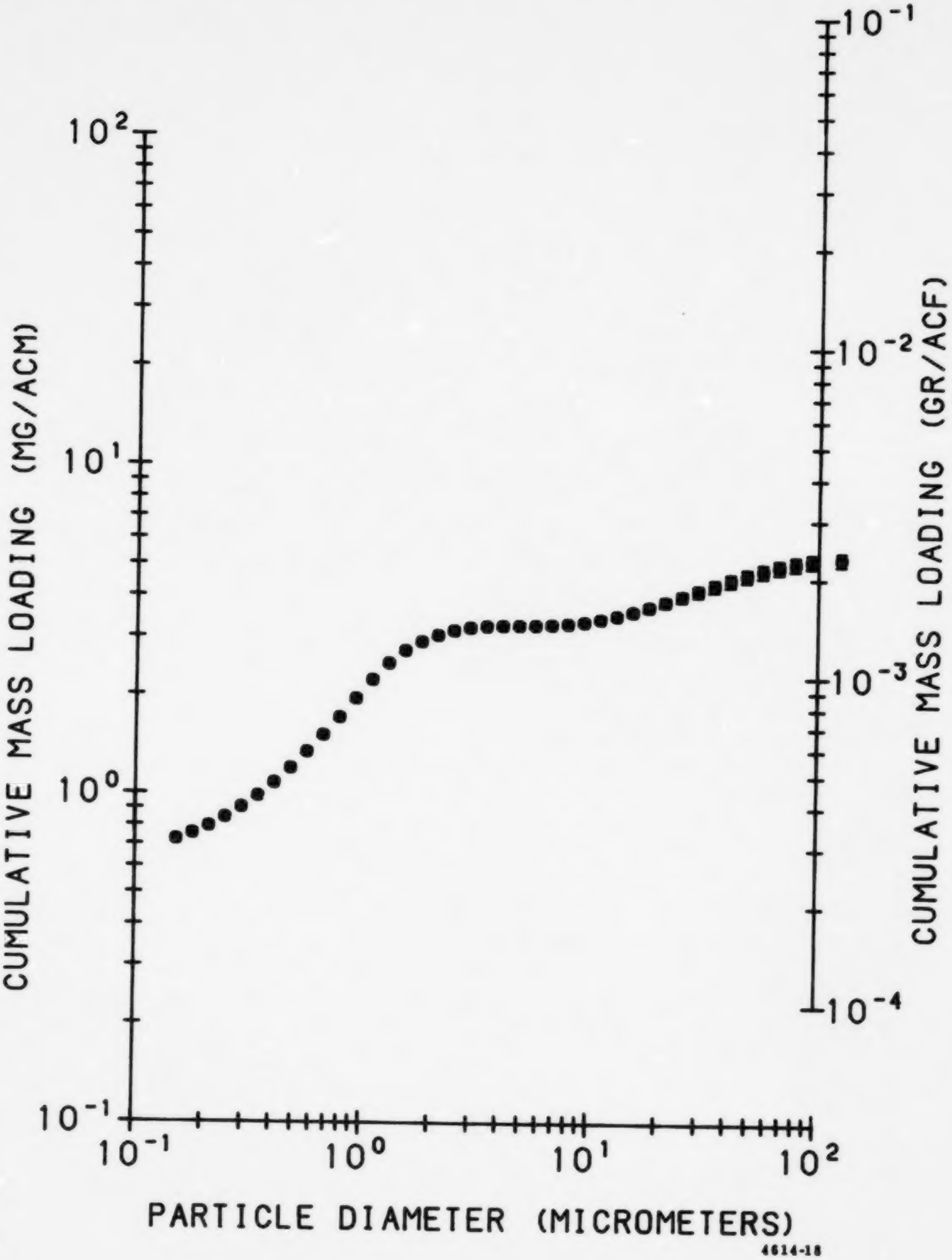


Figure 11. Scrubber size distribution on cumulative mass concentration basis.

particles may not be as useful for the purpose of identifying the contribution of a source to the ambient particulate loading as size specific compositional data would be; especially if size specific information were available for both the source(s) and the ambient. In order to obtain such size specific information for the source, samples were taken for determining the composition of the emissions from the Scholz plant in six size fractions. These samples were obtained at stack conditions using SoRI series cyclone systems. Because the samples were collected in-situ, the results may not accurately reflect the concentrations of some elements in the particles after the flue gases are discharged and cooled. The coarsest of the six fractions included all particles larger than about 8 μm, and the finest, those smaller than about 0.3 μm. The samples represent integrated emissions over a five day period. Specimens from each size fraction were submitted to Columbia Scientific Laboratory for analysis by (energy dispersive) x-ray fluorescence, and to North Carolina State University for neutron activation analysis. The results of these analyses, expressed as concentrations at flue gas conditions for each size fraction, are given in Tables 8 and 9. Also shown in Table 10 are the results of simultaneous analyses of NBS reference flyash samples which were included as blind controls in the samples submitted to the analytical laboratories. The results of mineral analysis by atomic absorption of an ash sample, after ignition, are given in Table 11. Reported concentrations of major constituents of the scrubber liquor are given in Table 12. Elements having high concentrations in the liquor might be expected to have higher concentrations in the plume than would be expected solely on the basis of the ESP exit emission measurements if significant liquor carryover occurs in the scrubber. Unfortunately, no sample of the scrubber effluent was collected for elemental analysis.

The results of XRF analyses of the diffusion battery filters are given in Table 13. In this table, the letter designation "A" refers to a sample taken with no diffusion battery; while the letters "B" through "D" refer to samples taken downstream of diffusion batteries having diffusional D_{50}'s of 0.016 μm, 0.032 μm, 0.064 μm, and 0.128 μm, respectively. The measured elemental penetrations of the diffusion batteries are consistent with the distribution parameters measured by the EAA. The mass median diameter of the submicron mode was about 0.08 μm from the diffusional data and the EAA results fell in the range from 0.06 to 0.2 μm depending on the time at which the data were taken. The diameters used in this comparison are estimated true physical diameters rather than aerodynamic. Also included in Table 13 are the results of similar analyses of the material collected by the backup filters of the series cyclones. The latter samples were taken at stack gas conditions rather than after cooling to ambient temperature. The diffusion battery samples were collected downstream of a pair of cyclones

TABLE 8. ELEMENTAL ANALYSIS OF IN SITU CYCLONE CATCHES UNIT #1 PLANT SCHOLZ

TABLE # 19 ELEMENTAL ANALYSIS OF INSITU CYCLONE CATCHES UNIT #1 PLANT SCHOLZ

		CYCLONE #1		CYCLONE #2		CYCLONE #3		CYCLONE #4		CYCLONE #5		FILTER	
		NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY
ALUMINUM (AL)	1	1322.221	847.998	206.431	223.501	271.434	220.483	39.723		10.576		1159.166	93.329
SILICON (SI)	2		1061.823		370.860		362.233						415.007
PHOSPHORUS (P)	3		24.986		8.513		11.596						13.131
SULFUR (S)	4		248.792		48.789		68.968						171.323
CHLORINE (CL)	5	1.207	10.575	0.000	1.755	0.000	1.602	-0.081		-0.081		0.196	2.140
POTASSIUM (K)	6		167.402	42.846	47.897		49.437	0.000				0.000	44.921
CALCIUM (CA)	7	110.547	72.181	25.779	13.723	19.668	16.479	0.000		0.000		202.232	16.461
TITANIUM (TI)	8	65.750	52.257	29.165	13.708	17.188	16.326	1.331		0.822		58.889	7.733
VANADIUM (V)	9	6.302	4.516	2.784	1.063	1.853	1.404	0.321		0.110		5.623	2.441
CHROMIUM (CR)	10	2.370	17.118	0.602	3.400	0.689	4.120	0.175		0.031		2.013	3.208
MANGANESE (MN)	11	3.135	67.795	1.867	12.931	0.094	15.106	0.203		0.064		2.695	5.739
IRON (FE)	12	2698.889	2423.475	409.745	433.524	441.000	509.324	65.747		17.140		1409.719	112.692
COBALT (CO)	13	0.990	48.777	0.241	8.460	0.281	10.376	0.038		0.009		0.848	4.181
NICKEL (NI)	14		1.585	0.156	0.718	0.000	0.847	0.000				0.032	2.231
COPPER (CU)	15	0.027	5.430	0.205	1.546	0.112	1.938	0.000		0.059		0.537	2.842
ZINC (ZN)	16	4.998	10.572		2.955		4.730	-0.034		-0.034			3.421
GALLIUM (GA)	17		0.000		0.000		0.000	0.000					2.712
GERMANIUM (GE)	18		0.000		0.000		0.000	0.000					3.801
ARSENIC (AS)	19	113.776	91.620	9.558	28.751	39.783	45.928	14.973		5.652		57.110	105.562
SELENIUM (SE)	20	1.035	5.308	0.111	0.625	0.106	0.931	0.000		0.004		0.500	2.757
BROMINE (BR)	21	0.869	11.477	0.127	1.729		1.961	0.017		0.003		0.451	4.375
RUBIDIUM (RB)	22	2.764	3.033	0.728	0.432	0.501	0.259		Not Analyzed	0.000	Not Analyzed	2.161	0.000
STRONTIUM (SR)	23		14.708		2.279		2.083						1.700
ZIRCONIUM (ZR)	24		4.060		0.796		0.595						1.952
LEAD (PB)	25		9.532		1.435		0.870	0.000					0.000
MERCURY (HG)	26	0.170	0.000	0.000	0.000	0.000	0.000	0.000		0.000		0.014	4.958
TUNGSTEN (W)	27		0.000		0.000		0.000	0.000					0.000
CADMIUM (CD)	28	1.068	0.000	0.352	0.000	0.000	0.000	0.223		0.000		0.000	0.000
TIN (SN)	29		0.000	0.000	0.000		0.000	0.000					0.000
ANTIMONY (SB)	30	1.071	6.196	0.170	0.000	0.442	1.083	0.106		0.041		1.091	3.186
BARIUM (BA)	31	20.276	36.840	5.423	4.885	3.582	5.035	0.000		0.000		35.335	14.098
IODINE (I)	32							0.000					
MAGNESIUM (MG)	33	110.366		27.115		18.651		2.141		0.507		179.689	
SODIUM (NA)	34	43.324		4.779		8.369		-0.019		1.015		29.414	
SAMARIUM (SM)	35	0.213		0.023		0.032		0.005		0.002		0.144	
CERIUM (CE)	36	2.144		0.294		0.223		0.016		0.012		0.805	
URANIUM (U)	37	0.196		0.033		0.077		0.008		0.002		0.208	
THORIUM (TH)	38	0.310		0.038		0.056		0.010		0.004		0.239	
LANTHANUM (LA)	39	1.423		0.143		0.190		0.038		0.010		1.746	
GOLD (AU)	40							0.000					
SILVER (AG)	41							0.000					
SCANDIUM (SC)	42	0.772		0.153		0.161		0.032		0.011		0.583	
EUROPIUM (EU)	43	0.037		0.006		0.007		0.000		0.000		0.025	
CESIUM (CS)	44							0.000					
MULYBDENUM (MO)	45	0.357		0.076		0.171		0.000		0.000		0.983	
LUTETIUM (LU)	46	0.025		0.004		0.003		0.000		0.000		0.036	
TELLURIUM (TE)	47							0.000		0.000			
YTTERBIUM (YB)	48	0.111		0.021		0.021		0.000		0.000		0.164	
HAFNIUM (HF)	49	0.107		0.021		0.020		0.000		0.000		0.169	
TERBIUM (TB)	50	0.030		0.011		0.003		0.000		0.000		0.046	
MASS AS OXIDES		16443.913		3409.918		3729.925		386.054		109.588		2972.846	
MASS AS SULFATES			746.375		146.367		206.903		0.000		0.000		513.968
CUM. OXIDE MASS		27052.244		10608.331		7198.413		3468.488		3082.434		2972.846	
CUM. SULFATE MASS			1613.614		867.238		720.871		513.968		513.968		513.968
STOKES DIAMETER		> 6.5		2.6 - 6.5		1.7 - 2.6		0.8 - 1.7		0.4 - 0.8		< 0.4	

ALL UNITS ARE MICROGRAMS / DNCM

TABLE 9. ELEMENTAL ANALYSIS OF IN SITU CYCLONE CATCHES
UNIT #2 PLANT SCHOLZ

		CYCLONE #1		CYCLONE #2		CYCLONE #3		CYCLONE #4		CYCLONE #5		FILTER	
		NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY
ALUMINUM (AL)	1	4217.959	2706.731	788.908	686.322	319.492	255.091	105.560	73.472	4.669		18.592	38.794
SILICON (SI)	2		4720.212		1206.168		416.392		127.489				189.576
PHOSPHORUS (P)	3		71.364		24.081		12.850		4.539				5.249
SULFUR (S)	4		504.645		169.617		78.637		39.557				56.977
CHLORINE (CL)	5		16.057		3.104		1.628	0.133	1.479	0.289		0.125	0.579
POTASSIUM (K)	6	3001.769	644.824	969.573	174.852	0.000	63.677		17.963				17.984
CALCIUM (CA)	7	554.497	186.056	90.850	44.498	75.530	20.331	38.596	7.652	0.000		0.000	7.132
TITANIUM (TI)	8	180.548	178.410	29.339	42.928	18.873	21.290	10.560	7.457	0.206		2.399	3.149
VANADIUM (V)	9	18.199	13.839	4.264	2.696	2.182	1.824	0.965	0.645	0.047		0.686	0.735
CHROMIUM (CR)	10	6.493	48.426	1.704	12.145	0.776	5.370	0.745	1.881	0.025		0.128	1.066
MANGANESE (MN)	11	6.071	206.446	2.020	45.545	1.188	19.947	0.497	5.966	0.024		0.090	1.374
IRON (FE)	12	7493.362	7610.450	1520.159	1556.920	569.941	690.471	205.102	198.626	9.265		26.688	41.415
COBALT (CO)	13	2.928	152.923	0.905	29.840	0.326	12.659	0.004	4.085	0.004		0.013	0.729
NICKEL (NI)	14		8.411	1.506	2.618	0.000	1.391	0.444	0.460				0.468
COPPER (CU)	15	1.346	19.498	0.127	5.575	0.057	2.666	0.037	0.947	0.015		0.407	0.979
ZINC (ZN)	16		30.585		10.994		6.329	1.123	2.659	2.147			1.040
GALLIUM (GA)	17		0.000		0.000		0.000	0.000	0.000				0.635
GERMANIUM (GE)	18		0.000		0.000		0.000	0.000	0.000				1.079
ARSENIC (AS)	19	263.216	341.527	177.515	158.100	52.142	70.773	53.556	37.417	3.116		30.351	31.623
SELENIUM (SE)	20	1.711	10.705	0.381	2.251	0.174	1.036	0.148	0.493	0.031		0.466	1.456
BROMINE (BR)	21	0.947	24.213	0.099	7.277	0.000	3.261	0.000	1.615	0.006		0.134	1.166
RUBIDIUM (RB)	22	9.106	4.970	2.353	1.518	0.636	0.537	0.224	0.000	0.000		0.138	0.321
STRONTIUM (SR)	23		28.673		6.387	0.000	2.685	0.000	0.879				0.477
ZIRCONIUM (ZR)	24		10.195		2.539	0.000	1.064	0.000	0.366				0.439
LEAD (PB)	25		0.000		3.508	0.000	1.908	0.000	0.428				0.711
MERCURY (HG)	26		0.000		0.000	0.000	0.000	0.000		0.003	Not Analyzed	0.037	1.257
TUNGSTEN (W)	27		0.000		0.000	0.000	0.000		0.000				0.000
CADMIUM (CD)	28	4.270	0.000	0.000	10.313	0.462	0.000	0.126	0.000	0.000		0.000	0.000
TIN (SN)	29		0.000		0.000	0.000	0.000		0.000				0.000
ANTIMONY (SB)	30	2.742	0.000	1.183	3.717	0.529	0.000	0.304	0.000	0.027		0.308	0.910
BARIUM (BA)	31	51.237	76.461	6.635	38.740	3.120	6.521	1.998	1.362	0.000		0.000	2.075
IODINE (I)	32					0.000							
MAGNESIUM (MG)	33	347.760		50.719		42.410		7.404		0.588		1.683	
SODIUM (NA)	34	86.801		42.997		9.666		5.098		0.219		2.706	
SAMARIUM (SM)	35	0.364		0.098		0.035		0.017		0.001		0.020	
CERIUM (CE)	36	0.000		0.543		0.274		0.167		0.009		0.026	
URANIUM (U)	37	0.330		0.140		0.087		0.000		0.002		0.136	
THORIUM (TH)	38	0.565		0.142		0.058		0.034		0.002		0.007	
LANTHANUM (LA)	39	2.619		0.761		0.281		0.108		0.007		0.000	
GOLD (AU)	40												
SILVER (AG)	41												
SCANDIUM (SC)	42	2.374		0.577		0.210		0.084		0.006		0.024	
EUROPIUM (EU)	43	0.133		0.026		0.009		0.004		0.000		0.001	
CESIUM (CS)	44					0.000							
MOLYBDENUM (MO)	45	4.395		0.480		0.253		0.058		0.000		0.000	
LUTETIUM (LU)	46	0.062		0.012		0.005		0.002		0.000		0.000	
TELLURIUM (TE)	47												
YTTERBIUM (YB)	48	0.243		0.068		0.021		0.013		0.000		0.000	
HAFNIUM (HF)	49	0.286		0.056		0.023		0.010		0.000		0.000	
TERBIUM (TB)	50	0.046		0.010		0.003		0.002		0.000		0.000	
MASS AS OXIDES		48705.062		11649.328		4708.977		1471.732		57.718		1018.073	
MASS AS SULFATES			1513.934		508.852		235.911		118.670		0.000		170.930
CUM. OXIDE MASS		67610.891		18905.829		7256.501		2547.523		1075.791		1018.073	
CUM. SULFATE MASS			2548.297		1034.363		525.510		289.600		170.930		170.930
STOKES DIAMETER		> 6.5		2.6 - 6.5		1.7 - 2.6		0.8 - 1.7		0.4 - 0.8		< 0.4	

ALL UNITS ARE MICROGRAMS / DNCM

TABLE 10. ELEMENTAL ANALYSIS OF "NBS - 1633" FLY ASH

				Replicate Analyses	
		'NBS VALUES'	NAA VALUE	XRAY VALUE	XRAY VALUE
ALUMINUM (AL)	1	125000.000	99168.720	68800.000	66500.000
SILICON (SI)	2	205000.000		114000.000	103900.000
PHOSPHORUS (P)	3	880.000		0.000	400.000
SULFUR (S)	4	5000.000		3800.000	3700.000
CHLORINE (CL)	5	0.000	72.780	860.000	1060.000
POTASSIUM (K)	6	16800.000	7733.000	10900.000	10500.000
CALCIUM (CA)	7	46000.000	33672.000	28700.000	28700.000
TITANIUM (TI)	8	7200.000	4334.120	4000.000	3900.000
VANADIUM (V)	9	214.000	174.630	105.000	104.000
CHROMIUM (CR)	10	131.000	112.870	500.000	600.000
MANGANESE (MN)	11	493.000	308.640	1600.000	1700.000
IRON (FE)	12	61800.000	59679.000	49700.000	52000.000
COBALT (CO)	13	39.300	38.790	1200.000	1000.000
NICKEL (NI)	14	98.000		0.000	0.000
COPPER (CU)	15	128.000	13.350	155.000	160.000
ZINC (ZN)	16	210.000		300.000	200.000
GALLIUM (GA)	17	0.000		0.000	0.000
GERMANIUM (GE)	18	0.000		0.000	0.000
ARSENIC (AS)	19	61.000	45.570	0.000	0.000
SELENIUM (SE)	20	9.400	8.920	0.000	0.000
BROMINE (BR)	21	8.600	5.540	0.000	0.000
RUBIDIUM (RB)	22	113.000	146.830	90.000	140.000
STRONTIUM (SR)	23	1410.000		1305.000	1370.000
ZIRCONIUM (ZR)	24	303.000		285.000	280.000
LEAD (PB)	25	70.000		0.000	0.000
MERCURY (HG)	26	0.140		0.000	0.000
TUNGSTEN (W)	27	4.300		0.000	0.000
CADMIUM (CD)	28	1.450	15.710	0.000	0.000
TIN (SN)	29	10.900		0.000	0.000
ANTIMONY (SB)	30	6.900	4.990	0.000	0.000
BARIUM (BA)	31	2690.000	1474.460	2400.000	2300.000
IODINE (I)	32	2.700			
MAGNESIUM (MG)	33	15500.000	6836.020		
SODIUM (NA)	34	3200.000	2378.580		
SAMARIUM (SM)	35	12.600	9.070		
CERIUM (CE)	36	149.000	141.530		
URANIUM (U)	37	11.600	11.150		
THORIUM (TH)	38	24.000	19.440		
LANTHANUM (LA)	39	84.300	73.210		
GOLD (AU)	40	0.000			
SILVER (AG)	41	0.000			
SCANDIUM (SC)	42	25.500	27.230		
EUROPIUM (EU)	43	2.740	2.440		
CESIUM (CS)	44	8.340			
MOLYBDENUM (MO)	45	31.000	0.980		
LUTETIUM (LU)	46	0.980	2.320		
TELLURIUM (TE)	47	0.000			
YTTERBIUM (YB)	48	6.550	5.610		
HAFNIUM (HF)	49	7.940	8.490		
TERBIUM (TB)	50	1.940	2.320		

UNITS ARE PPM OR MICROGRAMS ELEMENT / GRAM MATRIX

TABLE 11. ASH ANALYSIS

ELEMENT	PERCENT AS OXIDE SORI AA ASHED	PERCENT AS ELEM. SORI AA ASHED	PERCENT AS ELEM. AS REC-EIVED	PERCENT AS ELEM. EDXRF UNIT 1	PERCENT AS ELEM. EDXRF UNIT 2	PERCENT AS ELEM. NAA UNIT 1	PERCENT AS ELEM. NAA UNIT 2
LI	.06	.0278715	.0196773				
NA	.25	.1854631	.1309369			.17	.454
K	2.48	2.058769	1.453491	1.26	1.52	5.88	<.15
MG	.85	.5126984	.3619651			.682	.71
CA	.8	.5717546	.4036588	.365	.41	1.09	.758
FE	27.7	19.37439	13.67832	14.93	16.1	14.7	14.22
AL	23.3	12.33099	8.705681	5.29	6.11	8.27	8.75
SI	42.3	19.77379	13.96030	9.26	10.83		
TI	1.35	.8093242	.5713829	.35	.415	.354	.414
P	.51	.2225749	.1571378	.14	.23		
S	.2	.6007419	.6007419	.99	1.4		
UNKNOWN	.2						
	100	56.46837					
LOI %	28						
SOLBL SO4	1.3						

TABLE 12. COMPOSITION OF SCRUBBER LIQUOR

ELEMENT	CONCEN. PPM
NA	36784
SO4=	80640
CL	3191
MG	750
CA	22
FE	6
HSO3-	50220
SO3-	32000

TABLE 13. CONCENTRATIONS OF ELEMENTS FROM DIFFUSION BATTERY AND CYCLONE FILTERS

	CONCENRATION FOR DIFFUSION BATTERY OR FILTER, UG/M3								
ELEMENT	A	B	C	D	E	CYC FIL 2/9	CYC FIL 2/10	CYC FIL 2/9	CYC FIL 2/10
MG	0.61	0.31	0.19	0.00	0.71	6.69	2.90		
AL	2.57	2.14	1.22	0.48	5.48	57.08	24.96	54.00	23.60
SI	25.57	22.35	15.20	5.01	44.96	521.12	198.25	273.60	105.50
P	0.47	0.42	0.19	0.04	0.98	13.42	6.19	7.20	3.31
S	1129.98	736.32	1501.48	1346.95	1225.77	141.86	57.21	81.70	32.25
K	1.43	0.95	0.96	0.35	2.41	67.35	26.75	25.60	10.40
CA	1.39	1.14	1.20	1.28	2.64	26.27	11.18	9.96	4.30
TI	0.73	0.54	0.28	0.00	1.32	14.78	5.83	4.58	1.72
V	0.51	0.21	0.44	0.31	0.51	2.99	1.15	1.08	0.39
FE	8.77	7.37	4.54	1.83	19.31	159.30	63.42	58.80	24.10
AS	22.33	20.93	8.66	5.41	210.60	121.32	47.89	45.00	18.20
SE	17.05	11.58	4.60	3.01	22.09	4.78	1.80	2.26	0.65
SR	16.44	8.58	26.72	24.41	17.51	10.99	4.11	0.59	0.37
MO	23.77	11.13	38.74	38.36	24.65	28.18	11.66		
SN	14.78	10.69	11.27	8.50	25.64	0.00	0.10		
SB	0.08	0.05	0.05	0.04	0.21	3.01	1.34	1.24	0.58
BA	0.22	0.26	0.45	0.17	0.48	6.81	3.15	2.31	1.84

TABLE 14. ENRICHMENT RATIO RELATIVE TO ALUMINUM

	ENRICHMENT RATIO								
ELEMENT	A	B	C	D	E	CYC FIL 2/9	CYC FIL 2/10	CYC FIL 2/9	CYC FIL 2/10
MG	0.24	0.15	0.15	0.00	0.13	0.12	0.12	0.00	0.00
AL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SI	9.93	10.46	12.42	10.45	8.20	9.13	7.94	5.07	4.47
P	0.18	0.20	0.15	0.09	0.18	0.24	0.25	0.13	0.14
S	438.88	344.50	1227.07	2809.09	223.60	2.49	2.29	1.51	1.37
K	0.56	0.45	0.79	0.73	0.44	1.18	1.07	0.47	0.44
CA	0.54	0.53	0.98	2.67	0.48	0.46	0.45	0.18	0.18
TI	0.28	0.25	0.22	0.00	0.24	0.26	0.23	0.08	0.07
V	0.20	0.10	0.36	0.64	0.09	0.05	0.05	0.02	0.02
FE	3.41	3.45	3.71	3.82	3.52	2.79	2.54	1.09	1.02
AS	8.67	9.79	7.07	11.27	38.42	2.13	1.92	0.83	0.77
SE	6.62	5.42	3.76	6.27	4.03	0.08	0.07	0.04	0.03
SR	6.38	4.02	21.83	50.91	3.19	0.19	0.16	0.01	0.02
MO	9.23	5.21	31.66	80.00	4.50	0.49	0.47	0.00	0.00
SN	5.74	5.00	9.21	17.73	4.68	0.00	0.00	0.00	0.00
SB	0.03	0.03	0.04	0.09	0.04	0.05	0.05	0.02	0.02
BA	0.08	0.12	0.37	0.36	0.09	0.12	0.13	0.04	0.08

which duplicated the final two of the 5 series system; however, the flowrate used for the diffusion system was about 25% greater than that of the 5 series cyclone. This resulted in the diffusion battery filter samples having a somewhat smaller upper particle size cutoff than those of the cyclone filters.

Enrichment factors relative to Al (element concentration/Al concentration) based on the data in Table 13 are given in Table 14. In most cases the enrichment factors are approximately equal for a given element for all the diffusion battery and cyclone samples. However, they are not equal for S, As, and Se, for which elements the diffusion battery results show much higher values than the cyclone backup filters. S and Se both show enrichments in the diffusion samples that are about 100 fold greater than in the cyclone samples and As shows values that are 5 to 10 fold greater. The volatility of H_2SO_4, AsO_3, and SeO_3 are all such that they would be expected to be predominantly in the vapor phase at stack conditions and well above saturation at ambient temperatures given the measured concentrations found in the diffusion battery samples. Because of the cooling method used in the diffusional sampling, significant losses of some of the "condensibles" may have occurred; therefore the concentrations (and enrichments) found from the diffusion battery samples for S, Se, and As must be considered to be lower limits to their true values.

Gaseous Emissions

SO_2 and NO_x emissions were determined by Lear-Siegler continuous emissions monitors operated by the plant. Corrections to the indicated concentrations were made based on regressions of the data provided by monitors with independent data obtained on a spot basis by SoRI. In the case of SO_2, the monitors were compared to data obtained manually using peroxide bubbler samples that were taken concurrently with the sulfuric acid determinations. The plant's monitors were found to produce values for SO_2 concentrations that were high by 65 to 350 ppm depending on the unit and test week. The magnitude of the offsets in the output of the SO_2 monitors shifted from week to week as a result of routine weekly calibration and span adjustments that were made by the plant operators. The NO_x data were checked by comparison with a TECO Model A10 NO_x Analyzer (chemi-fluorescent analysis) that was calibrated twice daily using bottled zero and span gases. The data reported here have been corrected for the instrumental offsets.

Samples were obtained from several ports in each duct to check for stratification in order to insure that proper corrections were made as both the manual SO_2 measurements and the TECO extractive probe used single point sampling. A more complete traverse was made with the NO_x analyzer than was the case for the SO_2 (and H_2SO_4) measurements. No detectable stratification was found in any case.

The results of the gaseous emissions measurements were summarized in Table 4. More detailed data on the results of the manual SO_2 and H_2SO_4 measurements are given in Tables 15 and 16. The measured values reported in this table were corrected to concentrations at a fixed O_2 content to account for the dilution that occurred at low loads when greater excess air was present. The dilution corrected SO_2 concentrations were found to vary linearly with the sulfur content of the coal and to be insensitive to load variations. The NO_x concentrations were load sensitive, varying approximately linearly with load from about 320 ppm to 560 ppm over the load range from 20 to 50 Mw. No more than 5% of the NO_x emissions were in the form of NO_2 prior to discharge to the atmosphere.

The results of the H_2SO_4 measurements revealed much more complex behavior. The concentrations differed systematically between the two units, with Unit 2 having concentrations that were generally about a factor of two higher than those for Unit 1. Dilution corrected H_2SO_4 concentrations are shown plotted versus flue gas temperature in Figure 7.3.3-1. At any given load, the flue gas temperatures for Unit 1 consistently ran about 5 to 10°C lower than those for Unit 2. Thus one might expect that lower acid concentrations might be measured for Unit 1 as compared to Unit 2 as a result of more condensation of the acid upstream of the ESP in the case of Unit 1 and the subsequent removal of the condensed acid in the ESP. However, the data indicates a consistent offset for all temperatures. This difference is not an artifact of a systematic error in temperature or acid concentration measurement as the same temperature measurement device and sampling system were used alternately on each unit, each day, in obtaining the data shown in Figure 12. The amount of scatter shown is reduced if the ratio of H_2SO_4 to SO_2 is plotted rather than simply H_2SO_4. This has the effect of compensating for both coal sulfur and dilution variations. Figure 13 illustrates the data plotted in such a fashion.

Because data were taken only at the ESP outlets there is no way to determine how much of the variability in the acid concentrations was induced by the boilers (and coal variations), and how much was caused by factors downstream of the boilers. Although the SO_2 concentrations were found to vary linearly with the sulfur content of the coal, no apparent trends were evident when the (dilution corrected) H_2SO_4 concentrations were compared to the coal sulfur content, as illustrated in Figure 14.

The problem of the variability in the acid data is compounded by an apparent correlation of the acid concentration with the particulate loadings at the ESP exits as shown in

- TABLE 15. SO_2 AND H_2SO_4 CONCENTRATIONS FOR UNIT 1

DATE	TIME	UNIT LOAD	% S IN COAL	TEMP. DEG. C	H2SO4 PPM	SO2 PPM	% O2	H2SO4 PPM @4.2%O2	SO2 PPM @4.2%O2	H2SO4 /SO2 X1000
1/29	947	37	3.47	148	3.00	2115	6.00	3.36	2369	1.42
	1100			143	2.40	2270	5.30	2.57	2429	1.06
	1315	38		149	4.10	2115	6.10	4.62	2385	1.94
	1403	36		148	5.60	1945	7.80	7.13	2475	2.88
	1515	24		132	3.00	1730	8.50	4.03	2325	1.73
	1550	21		128	2.30	1690	9.10	3.25	2386	1.36
1/30	913	21	3.88	123	1.60	2050	8.40	2.13	2733	0.78
	956	21		123	1.30	2080	8.40	1.73	2773	0.63
	1300	31		133	2.30	2175	6.90	2.74	2591	1.06
	1331	31		133	2.70	2165	6.90	3.22	2580	1.25
2/2	1535	48	3.53	155	4.30	2020	5.40	4.63	2175	2.13
	1610	48		157	3.80	1785		4.09	1922	2.13
2/3	925	48	3.14	152	3.50	2065	5.70	3.84	2267	1.69
	1052	48		153	3.60	2050		3.95	2251	1.76
	1217	48		152	2.8	1970		3.07	2163	1.42
2/4	1336	48	2.6	154	1.70	1875	5.10	1.80	1981	0.91
	1500	48		156	1.70	1895		1.80	2002	0.90
2/5	756	48	3.14	154	1.90	1910	5.40	2.05	2057	0.99
	923	48		153	2.60	1930		2.80	2078	1.35
	1114	48		149	1.40	1785		1.51	1922	0.78
	1258	48		150	1.20	1800		1.29	1938	0.67
2/9	1416	48	3.29	156	4.60	2105	5.40	4.95	2267	2.19
	1500	48		157	4.70	2080		5.06	2240	2.26
2/10	850	48	3.6	152	1.80	1985	4.90	1.88	2071	0.91
	1010	48		153	1.90	2070		1.98	2160	0.92
	1044	48		153	2.00	2065		2.09	2155	0.97
2/11	1403	48	3.57	152	4.70	2300	4.70	4.84	2371	2.04
	1447	48		152	4.80	2240		4.95	2309	2.14
	1603	48		152	5.00	2280		5.15	2350	2.19
2/12	826	48	3.39	147	3.30	2225	5.10	3.49	2351	1.48
	904	48		146	2.70	2170		2.85	2293	1.24
	1049	48		146	3.00	2180		3.17	2303	1.38

TABLE 16. SO_2 AND H_2SO_4 CONCENTRATIONS FOR UNIT 2

DATE	TIME	UNIT LOAD	% S IN COAL	TEMP. DEG. C	H2SO4 PPM	SO2 PPM	% O2	H2SO4 PPM @4.2%O2	SO2 PPM @4.2%O2	H2SO4 /SO2 X1000
1/26	1403		3.34	134	NA	1300	9.60			
	1515			134	4.50	1330		6.63	1960	3.38
1/27	1038	43	3.10	157	7.20	1645	5.70	7.91	1806	4.38
	1331	35		148	6.00	1560	7.10	7.25	1885	3.85
	1447	28		138	3.90	1335	8.70	5.33	1823	2.92
1/28	854	23	3.62	134	4.10	1570	8.70	5.60	2144	2.61
	1030	21		130	4.30	1775	8.80	5.92	2444	2.42
	1123	20		129	4.40	1750	9.00	6.16	2450	2.51
2/2	835	50	3.49	159	7.40	1540	5.40	7.97	1658	4.81
	940	50		160	8.00	1540		8.62	1658	5.19
	1105	50		161	10.00	1810		10.77	1949	5.52
	1144	50		162	9.20	1665		9.91	1793	5.53
	1337	50		163	11.00	1840		11.85	1982	5.78
2/3	1523	50	3.20	158	6.50	1665	5.70	7.14	1828	3.90
2/4	825	50	2.92	159	6.50	1750	5.80	7.18	1934	3.71
	1005	50		162	7.00	1705		7.74	1884	4.11
	1042	50		162	7.40	1660		8.18	1835	4.46
2/5	1459	50	2.93	162	5.40	1765	5.20	5.74	1877	3.06
	1540	50		162	5.70	1755		6.06	1866	3.25
2/9	903	50	3.07	159	7.10	1610	5.60	7.75	1756	4.41
	937	50		161	7.30	1665		7.96	1816	4.38
	1121	50		162	6.30	1710		6.87	1865	3.68
	1154	50		162	6.70	1820		7.31	1985	3.68
2/10	1431	27	3.36	141	3.30	1675	8.10	4.30	2181	1.97
	1608	24		136	3.50	1775		4.56	2312	1.97
2/11	826	50	3.60	154	3.80	2485	4.70	3.92	2561	1.53
	1003	50		156	3.40	2500		3.50	2577	1.36
	1040	50		157	3.80	2460		3.92	2535	1.54
2/12	1355	48	2.96	153	6.30	1975	5.10	6.66	2087	3.19
	1533	38		150	6.00	1875	6.00	6.72	2100	3.20
2/13	810	50	3.74	153	2.00	2230	5.00	2.10	2342	0.90
	848	50		154	3.00	2210		3.15	2321	1.36
	1018	50		157	4.90	2070		5.15	2174	2.37

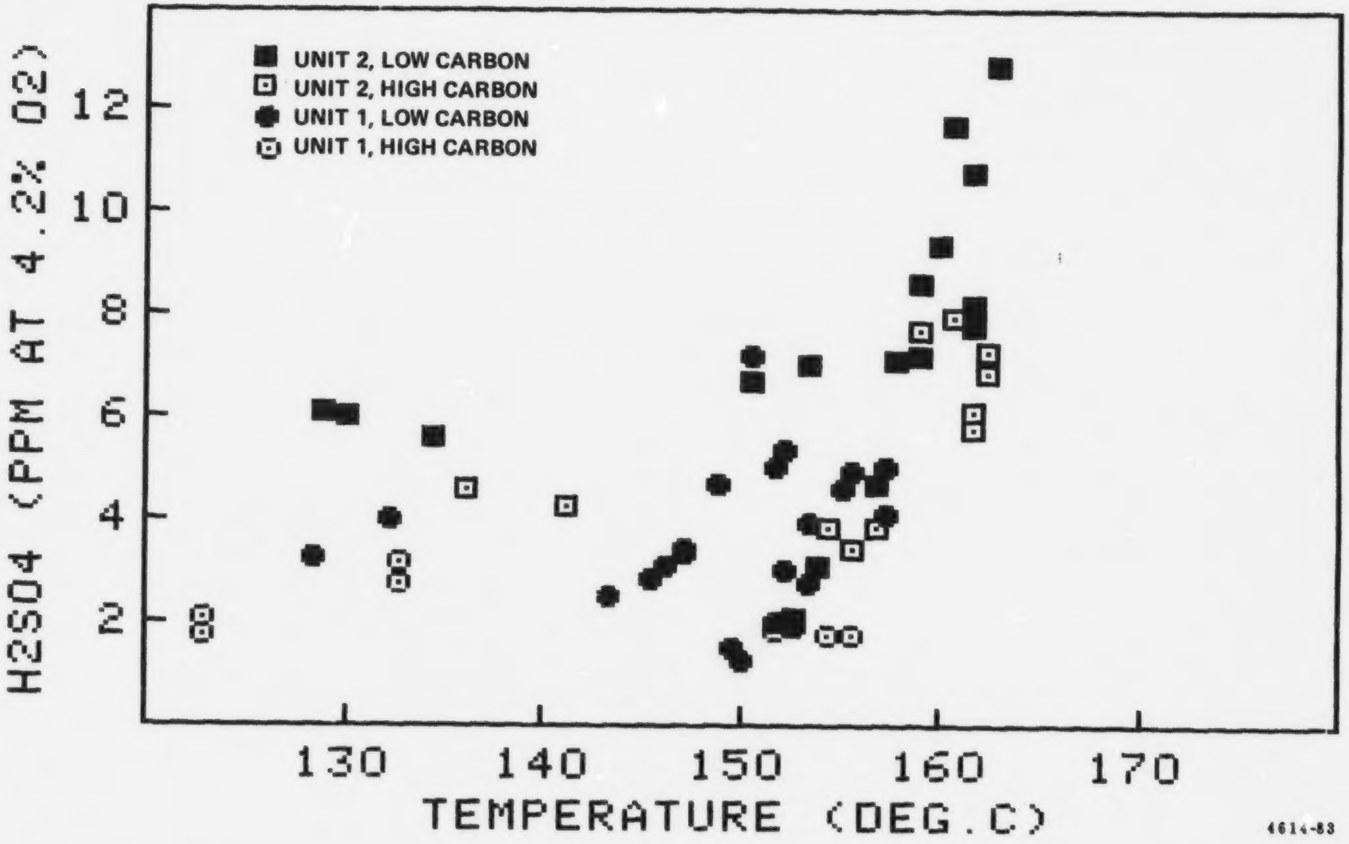


Figure 12. Sulfuric acid concentrations after correction to constant O_2 concentration versus flue gas temperature.

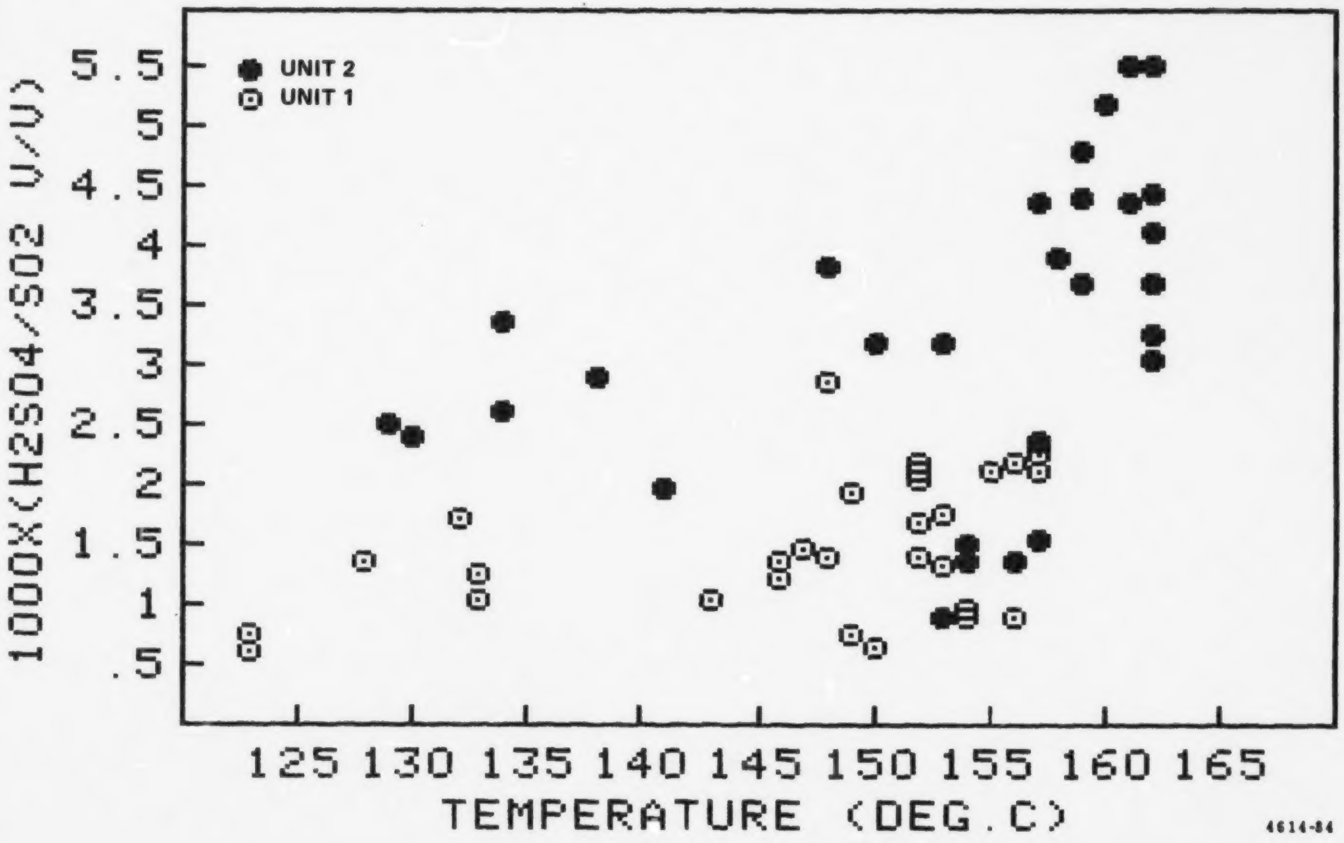


Figure 13. Ratio of sulfuric acid to sulfur dioxide concentrations versus flue gas temperature.

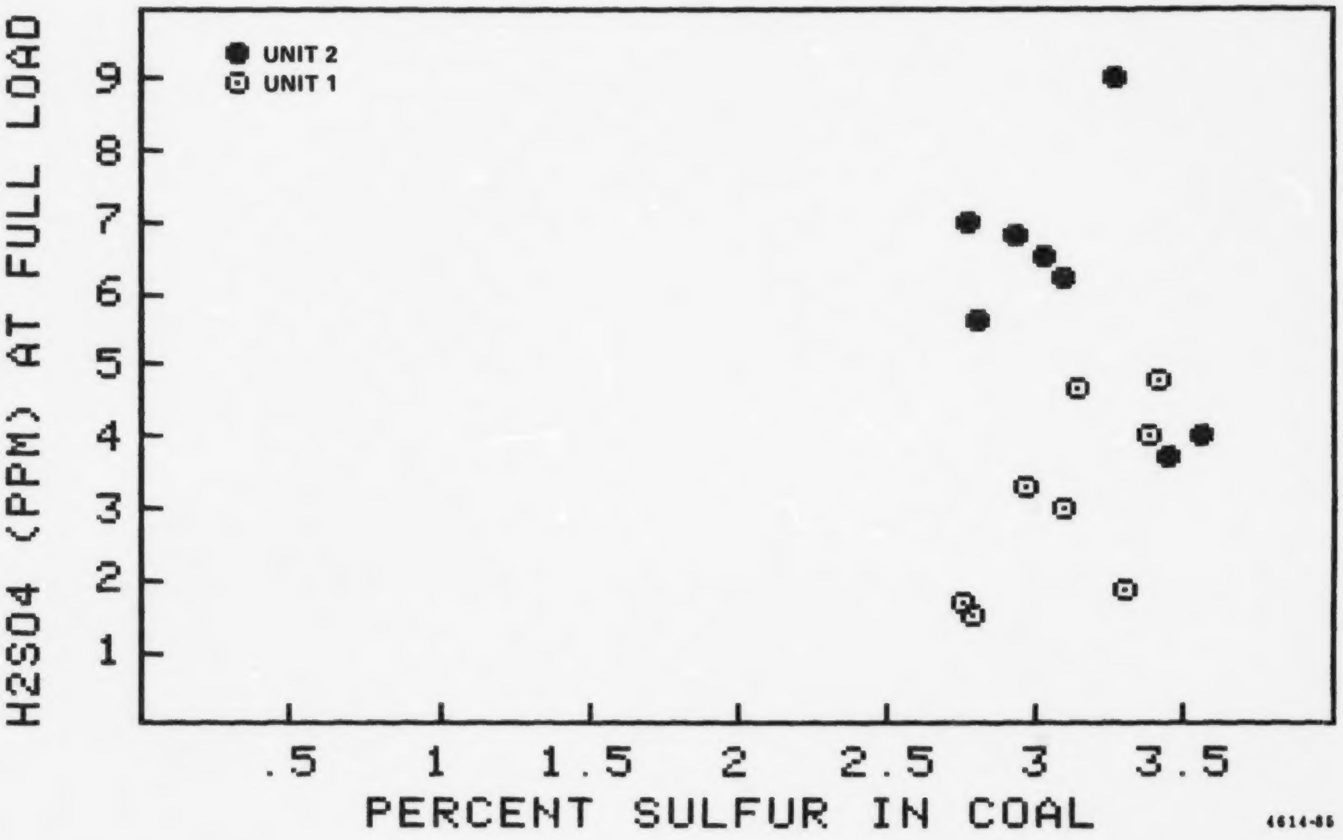


Figure 14. Sulfuric acid concentration at full load versus coal sulfur content.

Figure 15. (Data obtained during periods of high particulate carbon concentrations are omitted in this figure.) This might be taken to imply that the bulk of the acid was in the condensed phase and thus would be affected by the ESP's in roughly the same fashion as the particulate matter. However, the Method 17 and cascade impactor data indicate that the measured H_2SO_4 found by the H&C method must have been in the vapor phase. A plot of the H_2SO_4 concentration versus the particulate sulfate concentrations from the cascasde impactors is shown in Figure 16. These data coupled with the results from the Source Dilution Sampling System force the conclusion that the quoted H_2SO_4 concentrations are those of a predominantly vapor phase component.

A great deal of the scatter in the full load acid concentration data appears to have resulted from the boiler upsets. Most of the low concentration values at full load that are seen in Figure 12 were the results of measurements that were made when the particulate emissions are known to have been high in unburned carbon and soot. It is thus plausible that in these cases, the acid concentrations were reduced by sorption on the surface of the carbon. Since most of the carbon in the boiler effluent would be collected by the ESP's, the sorbed acid would also be removed from the flue gases and thus the acid concentration would be reduced in the ESP exhausts.

Figure 17 compares the measured H_2SO_4 concentrations with those predicted by the Banchero and Verhof equation[61] for the saturation concentrations at 10% moisture. At low load (and low measured concentrations) the measured values range from 1/3 of the predicted values to equal to the predictions. At full load the measured values are 5% to 20% of the theoretical predictions. The ratio of the concentrations of sulfur in the form of sulfate as compared to SO_2 in the stack gases ranged from a low of 0.06% to 0.6% with a typical value near 0.2%. The ratio was consistently higher for Unit 2 than for Unit 1 and tended to rise as the flue gas temperature increased. This ratio was plotted vs. temperature in Figure 13. From 120 to 165°C, the ratio, within the scatter of the data, varies linearly with temperature for each unit, with a common slope for the two units. Predictive equations based on linear fits to these data were used to obtain estimates of H_2SO_4 emissions for time periods in which measured values were not available.

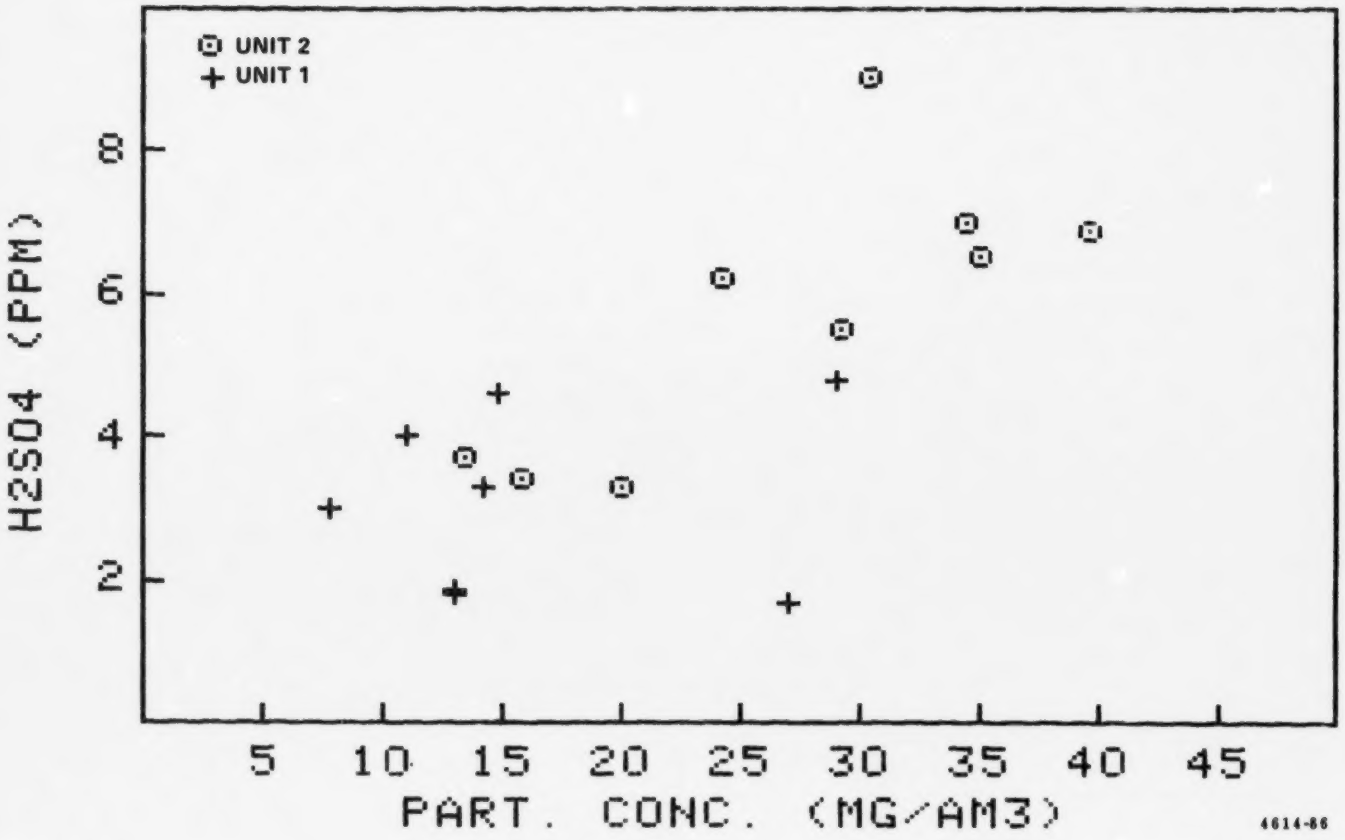


Figure 15. Sulfuric acid concentration versus particle concentration.

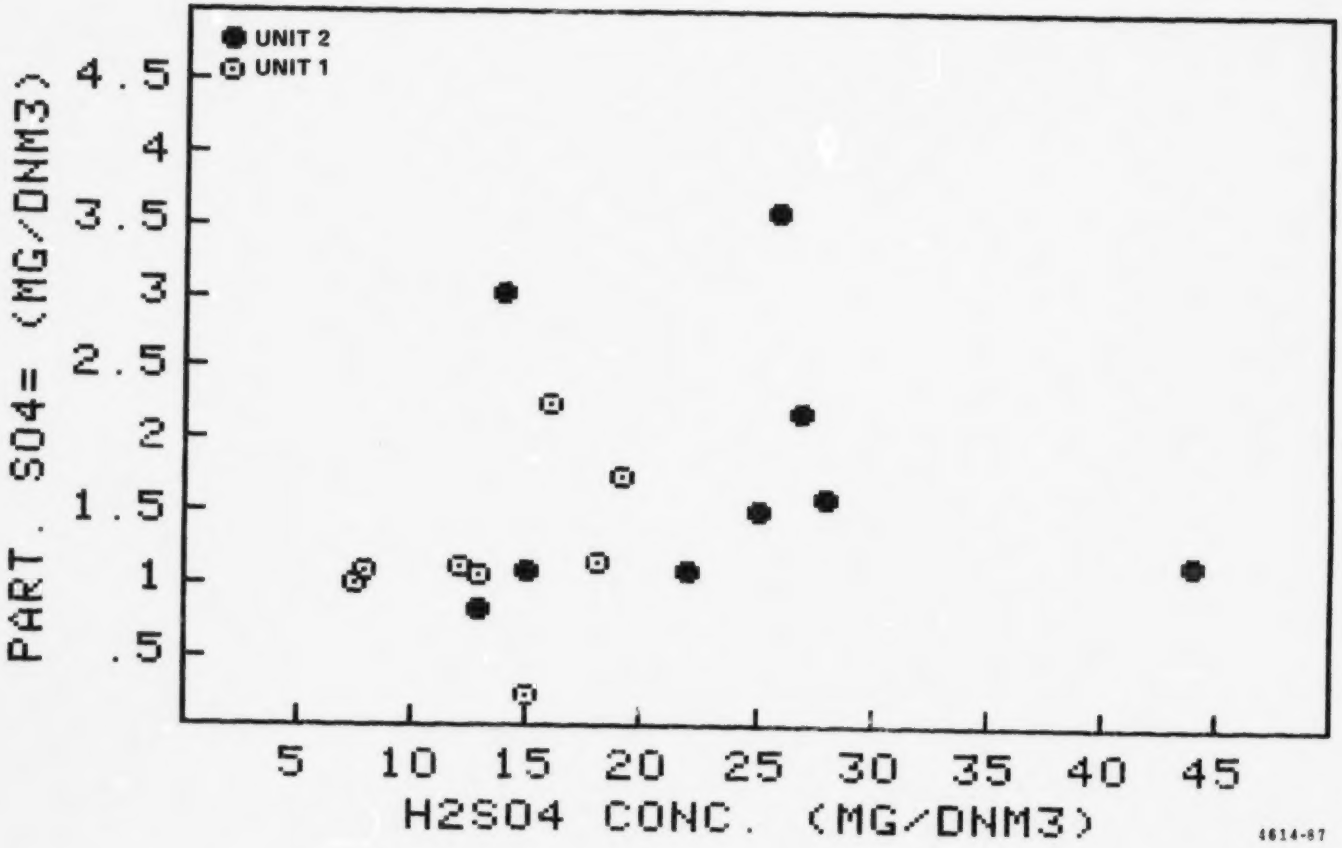


Figure 16. Particulate sulfate concentration versus sulfuric acid concentration.

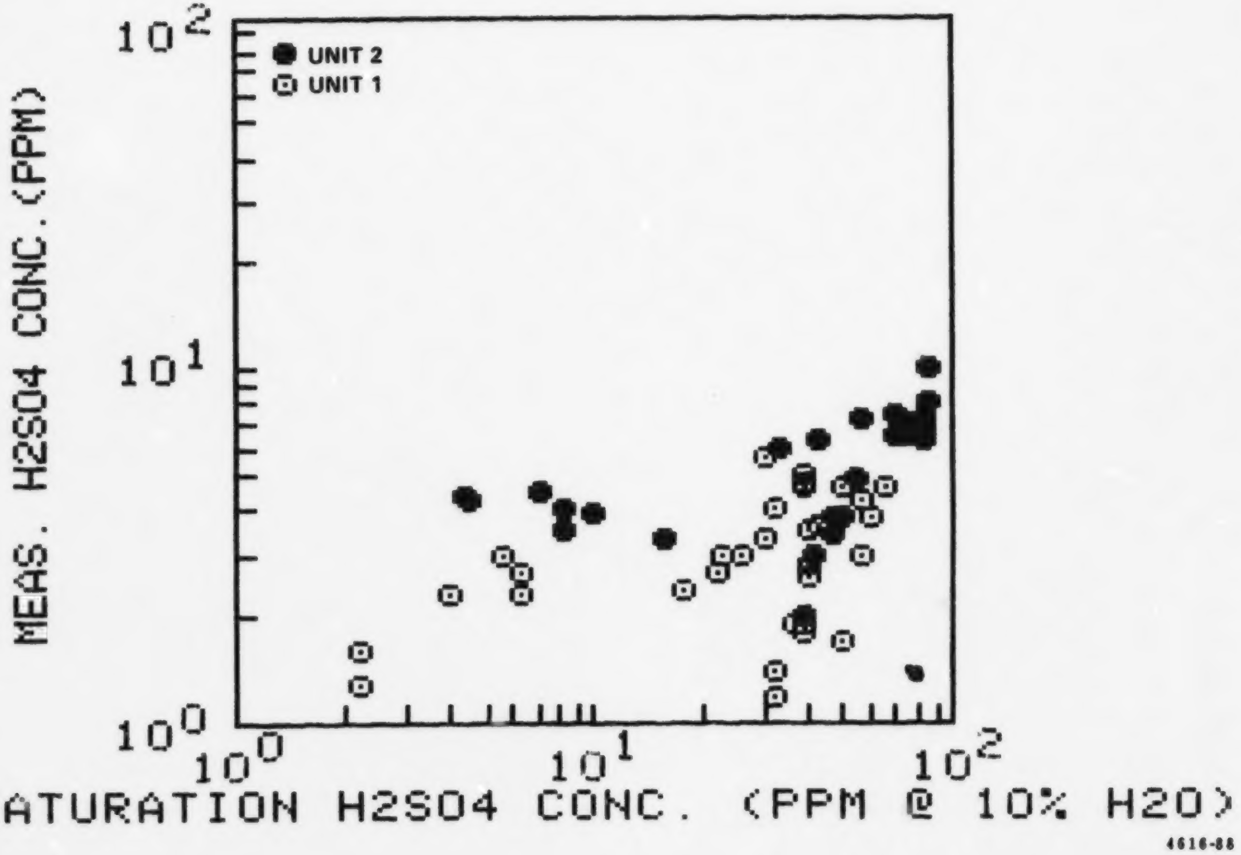


Figure 17. Measured sulfuric acid concentration versus saturation concentrations predicted by the Banchero and Verhof equation.

SECTION 8

AMBIENT MEASUREMENTS

MONITORING SITE LOCATIONS

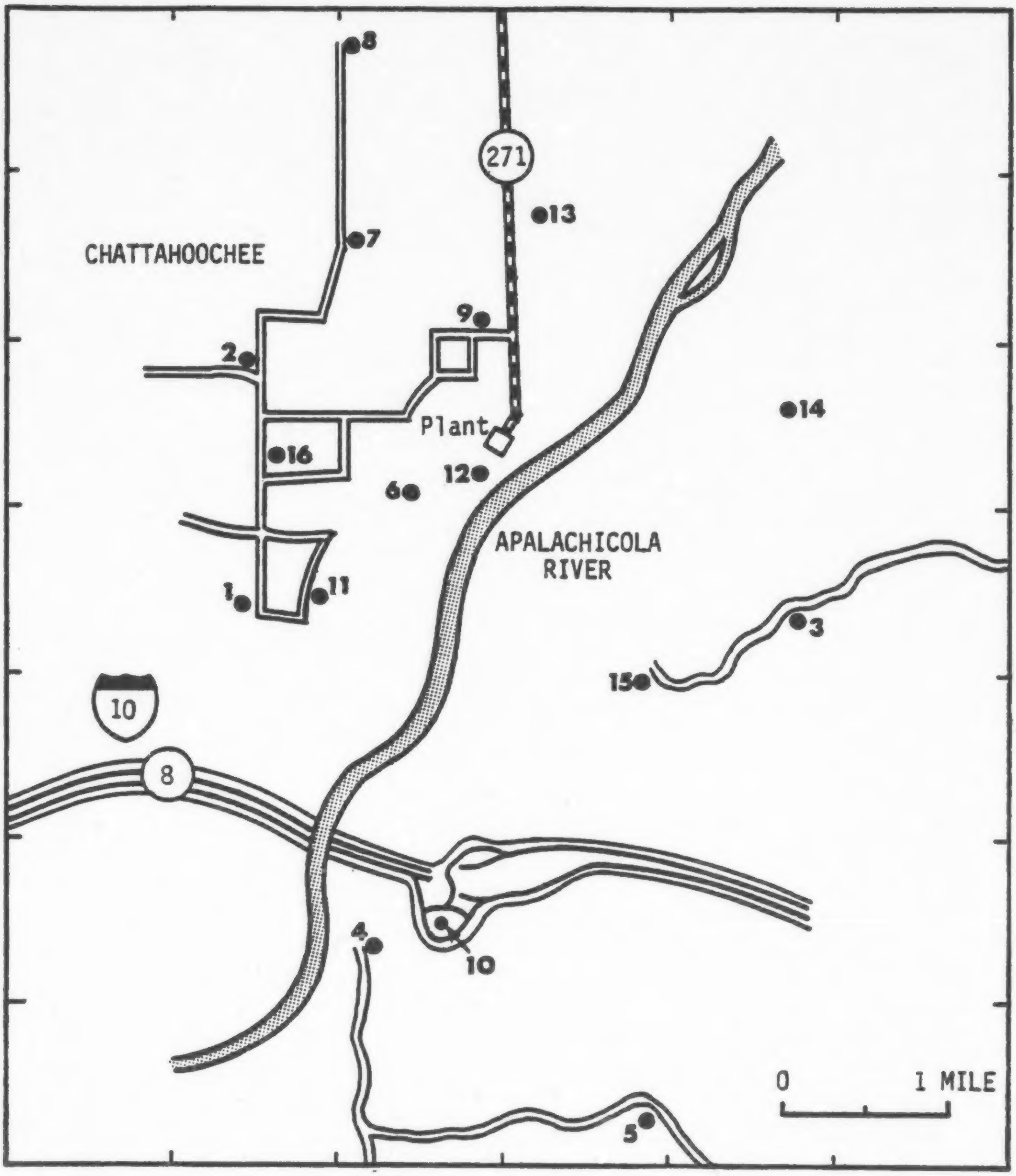
A grid of acceptable monitoring locations was developed in the vicinity of the plant and, based on anticipated wind flow, sites were selected for monitoring at the beginning of each test day. Wind flow was monitored throughout the course of each test day and when practical, the monitoring sites were changed when winds shifted, to maximize the amount of data obtained in the plume. The monitoring sites were selected as much as possible to lie in open areas where the prevailing wind flow was not significantly disturbed by local topography or vegetation. Also, sites near other local sites of pollutant emissions (e.g. residential trash burning) were avoided.

The movement of the sampling locations to remain in the plant plume obviously biases the samples toward over-estimation of the impact of the plant on the locale downwind of the plant. However, the mobility of the sampling stations avoided problems like those encountered in previous studies of this type in which fixed sampling station locations were used. In one such study, in which five fixed sampling locations were used, the authors of the report state: "The presence of local sulfate sources was detectable by the monitoring network; however, the plume from the plant tended to pass over or between the monitoring stations during most of the (four week) sampling period".[62]

A map of the area is given in Figure 18 showing the locations of the actual sampling sites that were used during the study. Table 17 identifies the bearing and distance of each monitoring location relative to the source.

TEST PROTOCOL

Data were collected at two mobile stations and at four fixed locations. The four fixed locations are those identified as sites 13 through 16 in Figure 18 and Table 17. These fixed stations are maintained by the Gulf Power Company and are used to monitor SO_2 concentrations in the vicinity of the plant. Depending on the wind direction, one of these four stations was utilized as an upwind monitoring station and others as downwind


CHATTAHOOCHEE
APALACHICOLA RIVER
Plant
271
10
8
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4
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10
11
12
13
14
15
16
0
1 MILE
4614-78

Figure 18. Location of acceptable monitoring sites near the Scholz Power Station, Chattahoochee, Florida.

TABLE 17. DISTANCE, DIRECTION, ELEVATION OF EACH DISCRETE RECEPTOR POINT RELATIVE TO SOURCE

Site ID Number	Distance of Site from Stack (meters)	Direction of Site from Stack (degrees)	Elevation of Site from Stack (meters)
1	2820	240	11.1
2	2500	290	12.0
3	3540	118	21.3
4	5000	194	13.9
5	6680	167	21.3
6	800	250	10.2
7	2500	327	9.2
8	970	341	9.2
9	1210	354	10.2
10	4670	188	20.4
11	2170	231	12.0
12	240	210	7.4
13	2250	12	8.3
14	2890	85	13.9
15	2660	147	20.4
16	2170	270	8.3

locations as appropriate. When used as a measurement site, a station was equipped with two suspended particulate samplers and a Lundgren cascade impactor. Site 16 was equipped with a nitrogen oxides sampler for the duration of the study. The two mobile stations were equipped with:

1. analyzers to measure sulfur dioxide and nitrogen oxides;
2. two hi-vol TSP samplers and a Lundgren impactor and;
3. a sulfuric acid mist sampler.

During each day of testing, meteorological data were collected to identify dispersion characteristics influencing emissions from the plant stack. A typical daily measurement routine included the following:

1. Review the National Weather Service forecast for the day;
2. Launch the first upper air sounding balloon;
3. Establish the plume transport direction;
4. Deploy the mobile sampling stations;
5. Secure the mobile stations and conduct calibration of samplers and monitors;
6. Collect air quality data and monitor plume transport direction;
7. Shut down monitors and complete documentation of field activities;
8. Leave air quality monitoring sites and return to plant.

Upper air soundings were repeated periodically throughout the daily sampling period to document changes in upper level temperature profiles, wind speed, and wind direction. In addition, wind speed and direction were monitored continuously at a height of 60 m (200 ft), using Gulf Power Company's on-site meteorological tower and instrumentation.

TEST RESULTS

A summary of the ambient data is given in Table 18. All values given in this table represent averages over the time periods during which the hi-vol samplers for sulfate and nitrate determinations were in operation. Soluble sulfate analyses were made on both the glass fiber and teflon filters. The results for the glass fiber filters are compared to those for the teflon filters in Figure 19. In general, the results from the glass fiber filters showed sulfate levels that were about a factor of 2.5 times as great as those from the teflon media. The difference is attributed to SO_2 uptake by the glass. Regression analysis of the sulfur concentrations from the x-ray fluorescence analyses of the teflon filters and the sulfur from the sulfate

TABLE 18. SUMMARY OF AMBIENT SAMPLING DATA

	LOCATION						ACID SYSTEM		TEFLON FILTER										WIND SPEED AT 6OM							
DATE	SITE #	POS WRT WIND	DIR.	PLANT DIST,KM	ROAD DIST,KM	TSP(1UM UG/DNM3	SO4 UG/DNM3	H2SO4 UG/DNM3	SULFATE UG/DNM3	% SO4	EDXRF S AS SO4 UG/DNM3	GFF SULFATE UG/DNM3	NITRATE UG/DNM3	NITRIC ACID UG/DNM3	NOX PPB	NO PPB	SO2 PPB	WIND DIR.	RANGE M/S	AVG. M/S	CLOUD COVER	STAB. CLASS	TEFLON FILTER ID	DUR MIN	START TIME	END TIME
1/28	6	C	250	0.00	4.83	56.60			3.86	6.82		10.26	<.015	1.74	NA	NA	NA	340					1	147		
1/29	6	C	250	0.00	4.02	24.90			1.8	7.23		3.34	.174	1.16	.14	.11	.05	100					2	371	1000	1611
1/30	1	C	240	2.02	3.20	33.70			3.06	9.00		6.96	.605	0.44	6.32	3.34	2.41	100	3-5				7	294	1015	1509
	16	C	270	2.17	3.70	32.10			2.83	8.82		6.29	.56	0.74	.435	0	0	100					5	465	855	1640
2/2	3	D	120	3.54	5.95	29.30			1.99	6.79	2.60	7.56	<.015	0.44	0.05	1.19	40.15	310	5-7	6	0	A-B	10	321	1139	1700
	16	C	270	2.17	4.03	13.00			1.37	9.93	2.82	2.11	<.015	0.25	0	0	0	310					8	635	700	1735
	15	D	150	2.66	6.44	65.90			2.04	3.10	2.70	7.49	<.015	0.20	0	0	0	310					9	123	1336	1533
2/3	3	C	120	3.54	5.95	20.70			.90	4.73	1.46	3.94	<.057	0.42	1.07	1.03	.46	340	4-6	4.5	0	A-B	12	430	850	1600
	16	C	270	2.17	3.70	NA			.75	NA	1.2	3.44	<.043	0.40	.537	0	0	340					11	559	730	1729
	15	D	150	2.66	6.44	NA			1.04	NA	1.69	5.11	.227	0.64	0	0	15.3	340					13	432	850	1602
2/4	4	C	195	5.00	1.61	51.50			1.82	3.53	3.36	8.95	<.140	1.60	6.30	1.59	2.60	270	3-5	4	.3	B-C	16	161	1100	1341
	16	U	270	2.17		25.70			1.56	6.07	2.04	3.82	.179	1.00	2.30	.22	1.25	270					14	559	830	1749
	5	C	160	6.60	1.61	56.70			1.04	3.25	2.50	5.36	.106	1.75	4.45	1.06	1.26	270					15	204	1030	1514
	14	D	85	2.09		NA				NA	NA	NA	NA	NA	NA	NA	40.15	270					NA		830	1750
2/5	1	D	240	2.02	0.00	30.70			2.36	6.10	3.12	6.1	.214	1.47	12.91	6.49	19.24	260	3-4	3.1	.5	B	18	406	815	1503
	6	D	250	0.00	6.40	35.10			3.91	11.14	6.3	7.2	<.299	1.45	59.71	44.11	175.01	320					19	80	900	1020
	13	U	13	2.25	2.09	33.00			1.06	5.50	2.56	5.62	.770	1.10	NA	NA	0	25					17	400	800	1440
2/6	12	C	210	0.24	4.00	9.30			.91	9.70	NA	1.13	<.050	NA	NA	NA	NA	120					24	400	800	1440
2/9	2	D-C	290	2.50	6.40	30.20	6.4	4.7	2.24	7.42	2.65	5.93	.126	1.37	4.13	.04	7.31	120	3-4	3.7	.3	B	21	351	915	1506
	16	D-C	270	2.17	6.40	10.00			2.01	15.61	3.45	5.05	.202	0.00	7.40	3.7	22.46	90					22	406	840	1551
	13	U	13	2.25		NA				NA		NA	NA	NA	NA	NA	16.3	90					20	NA	815	1600
	1	C	240	2.02		NA	6.3	3.7		NA		NA	NA	NA	5.63	3.10	5.25	90							815	1640
2/10	8	D	341	4.03	0.05	53.20	13.0	0.65	4.27	8.03	6.24	14.44	.157	0.20	10.91	3.91	23.91	160	10-12	12	1	D	27	404	825	1633
	13	D	13	2.25	6.44	49.50			5.93	11.90	7.60	3.59	.011	0.16	NA	NA	5.64	170					25	570	819	1857
	9	D	355	1.21	5.31	111.40	22.90	10.53	7.59	6.01	9	19.34	.494	0.63	61.91	36.31	145.01	160					26	427	900	1335
2/11	15	D	150	2.66	6.44	36.10			5.02	13.91	6.6	11.80	<.073	0.70	NA	NA	49.7	315	8-11	9	.5	C-A	30	327	1220	1755
	3	D	120	3.54	5.95	20.00	0.41	5.01	4.46	15.93	5.67	12	<.073	0.51	0.11	5.01	11.71	315					29	320	1132	1700
	13	C	13	2.25	2.09	21.50			4.64	21.50	5.55	6.73	.003	0.05	NA	NA	0	315					31	435	1034	1749
	12	U	0	.2			0.7	6							NA	NA	NA									
2/12	11	D	230	2.17	0.00	41.40			2.92	7.05	3.93	10.73	<.005	0.77	12.01	6.07	39.31	30	6-9	6.5	0	A	28	279	1230	1709
	10	D	187	4.67	0.40	20.70			2.35	11.35	3.15	5.43	.716	0.76	7.19	3.81	5.91	30					32	435	845	1600
	15	C	150	2.66	6.40	16.10			2.10	13.54	2.74	3.73	.153	0.53	NA	NA	0	30					33	1433	810	803
2/13	11	D	230	2.17	0.00	47.90			4.46	9.31	5.67	12.3	.371	0.74	17.41	5.13	113.01	30	4-6	5.8	1	A-B	34	317	925	1442
	12	D	210	0.24	5.20	42.30			7.66	10.11	9.70	13.72	.601	0.92	77.61	51.01	144.01	30					36	360	840	1440
	15	C	150	2.66	6.60	23.70			4.40	10.90	5.37	NA	.630	0.61	NA	NA	.32	30					35	522	823	1705

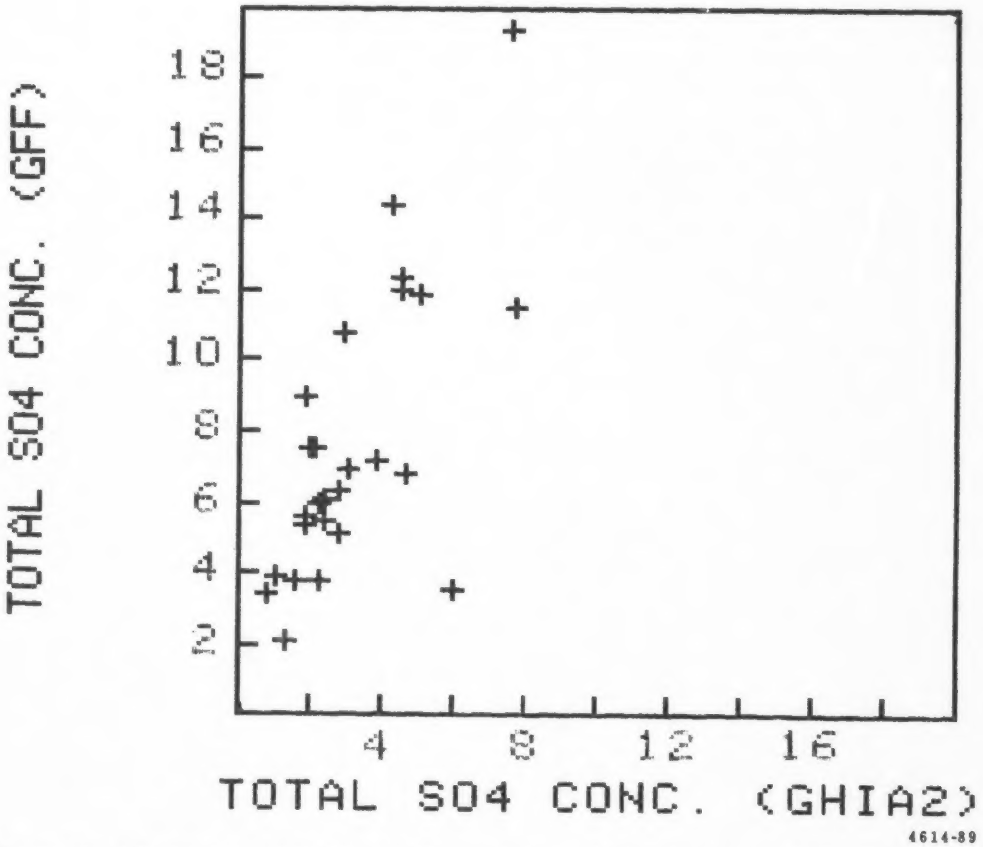

Figure 19. *Comparison of ambient sulfate concentrations as determined from samples taken on glass fiber and teflon filter media.*

analyses showed a correlation coefficient of 0.99 with the CSI XRF values systematically low by 25%. Other XRF analyses performed by the EPA Environmental Sciences Research Laboratory resulted in values that were 10% larger than those from the IC sulfate analysis.

A summary of the meteorological conditions for each day is given in Table 19. Vertical atmospheric temperature profiles form the pilot balloon releases are shown in Figures 20 and 21. These show that inversions at an altitude of about 800 m persisted throughout most of the tests. The mixing of air masses is inhibited at the elevation of such inversions. This causes pollutants emitted by the plant to remain close to the ground and slows the process by which they are diluted by the ambient air.

The data for each day are described more thoroughly in the following paragraphs. These detail the locations of the sites selected for each days sampling efforts, the amount of time each site was in the plume, and observed pollutant concentrations. The measured concentrations of the gaseous pollutants over the entire test period are given in Table 20. Exemplary concentrations are presented in graphic form together with wind direction information as appropriate in the paragraphs that follow.

Daily Summaries

Test 1 - 1/29/81

On this date a high pressure system was centered northwest of the Chattahoochee area. Winds were light and variable, (wind speeds 0-5 mph) with southerly wind directions most prevalent. Skies were generally clear; however, high sirrus clouds moved into the area in the afternoon. Sites 6 and 13 were selected for air quality monitoring. A complete set of instrumentation was used at site 6, but at site 13 no NO_x analyzers or hi-vols were run. The data collected at site 6 was representative of background conditions. The plume occasionally impacted site 13 as the winds shifted through the south-southwest sector. The maximum concentrations at site 13 were expected when the wind was from a bearing of 192 degrees. Background concentrations approached zero for both SO_2 and NO_x.

The plume impacted site 13 between 1400 and 1500 hours and again at 1800 hours. The highest observed SO_2 concentration was approximately 150 ppb at 1410. The continuous analyzer data collected at site 13 is illustrated in Figure 22.

TABLE 19. METEOROLOGICAL DATA

DATE	TIME	TEMP DEG.C	R.H. %	DEW POINT DEG.C	LAPSE RATE	INV. HGT,M	CLOUD COVER %
1/29	1140	18.00					0
	1350	19.00	26	-1.10	A		HI.SIR
1/30	830	10.60	62	3.60	A	600	0
	1110	19.40	42	6.30	A		
	1420	24.20	44	11.20	A		80-85
	1625	20.60	56	11.20	A		80-85
2/2	900	6.10	58	-1.40	A		0
	945	7.80	58	0.00	A		0
	1105	10.00	48	-0.20	A		0
	1205	8.90	42	-1.80	A		0
	1300	10.60	39	-2.80	A		0
	1410	11.40	38	-2.50	A		0
	1520	12.50	30	-4.70	A		0
	1710	8.60	42	-3.60	A		0
2/3	835	-1.70			A		0
	915	-0.40			A		0
	1020	1.10	43	-0.10	A		0
	1110	3.30	41	-8.60	A		0
	1200	3.90	43	-7.60	A		0
	1550	6.90	29	-9.90	A		0
2/4	836	5.50	34	-9.20	I		0
	1500	18.70	26	-6.40	A		80
2/5	800	3.60	46	0.00	I	1300	0
	935	6.80	36	-7.80	A	1500	35
	1010	6.70	32	-8.60	A	1200	
	1140	9.20	38	-4.60	A		
	1335	12.80	36	-2.10	A	900	90
	1435	11.00	30	-5.90	A		
	1510	11.80	22	-9.20	A		
2/9	830	6.70	58	-0.90	A	200	20-50
	950	10.90	41	-1.70	A	500	20-50
	1050	13.10	42	0.60	A		20-50
	1220	13.60	41	0.20	A	800	20-50
	1610	15.80	26	-3.40	A	800	20-50
2/10							RAIN
2/11	1120	8.90	71	4.00	A	900	100
	1300	6.90	63	0.30	A	900	75
	1410	6.90	52	-2.20	A	900	0
	1575	7.50	44	-3.90	A	900	0
	1640	4.30	47	0.70	I	1200	0
2/12	800	-3.60			A	700	0
	1015	0.00	40	-3.40	A	700	0
	1245	5.30	30	0.00	A	700	0
	1510	5.70	28	0.30	A	700	0
	1710	4.40	51	-9.10	A	700	0
2/13	1015	6.90	56	-1.10	A	500	100
	1150	8.20	60	1.00	A	500	100
	1313	8.20	54	-0.60	A	500	100
	1424	9.30	52	0.10	A	500	100
	1522	9.70	54	0.80	A	500	100

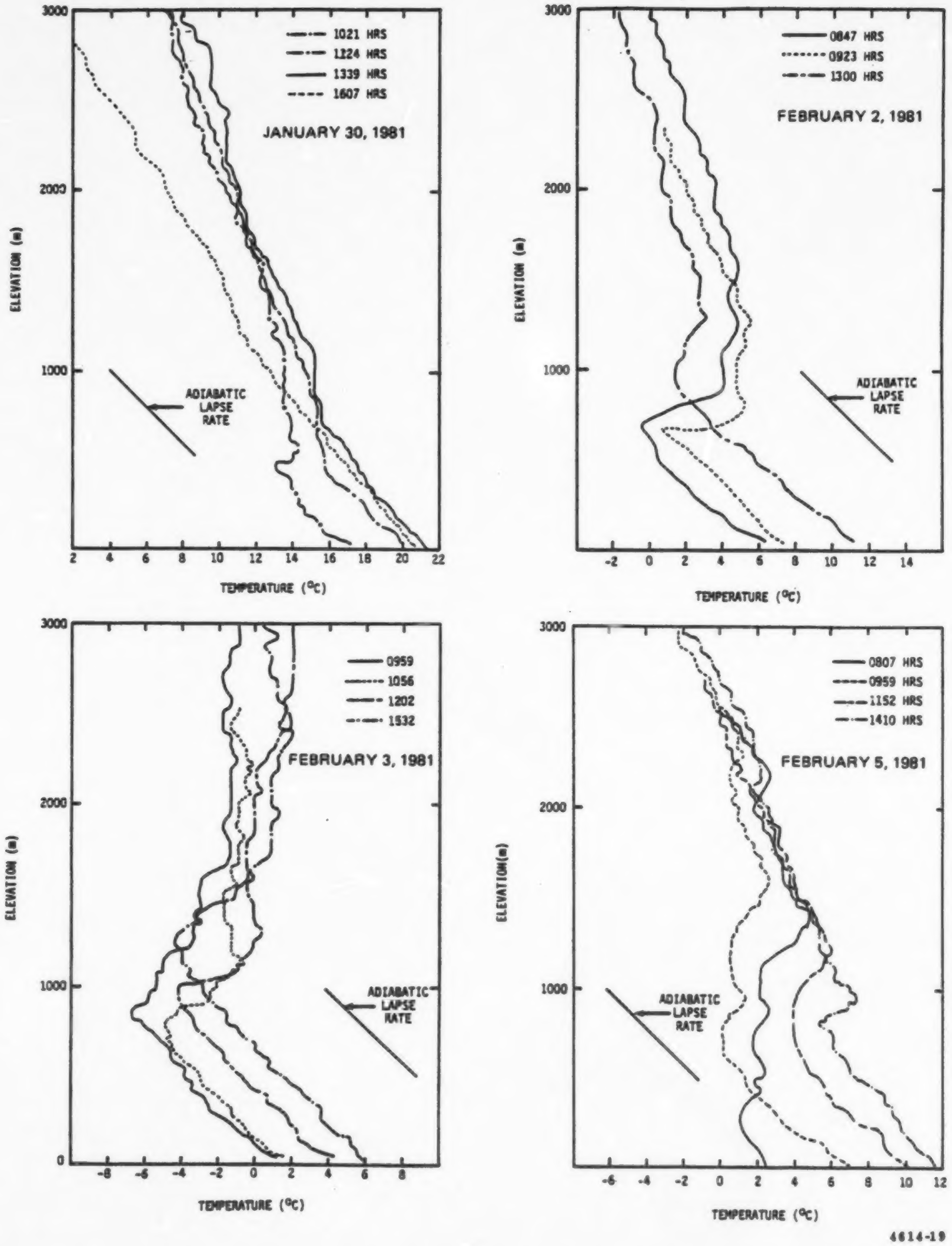

Figure 20. Ambient air temperatures for various pilot balloon launch times.

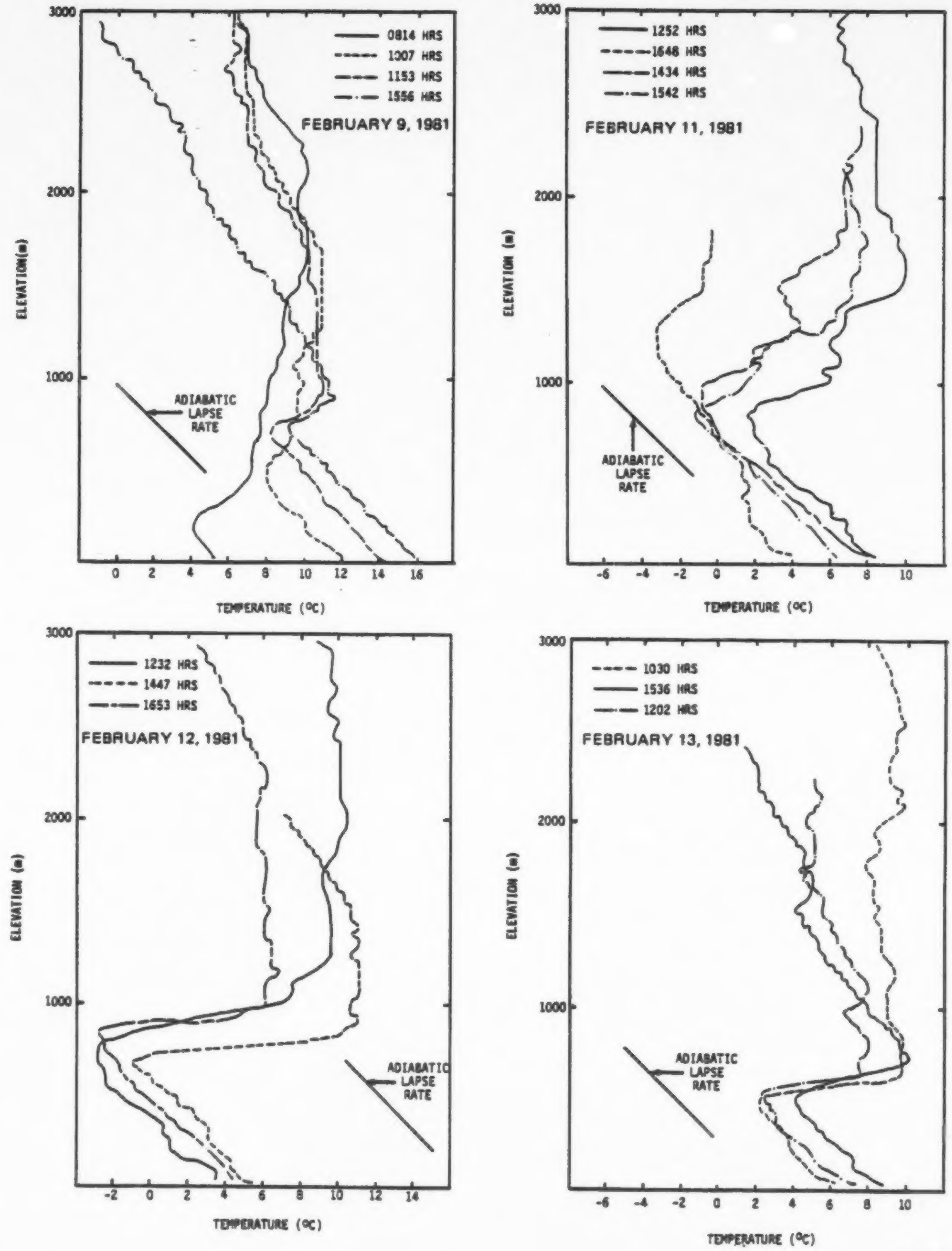

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Figure 21. Ambient air temperatures for various pilot balloon launch times.

TABLE 20. SCHOLZ AMBIENT SO_2 AND NO_x CONCENTRATIONS

SCHOLZ AMBIENT SO2 AND NOX CONCENTRATIONS

DATE:	1/29/81				1/30/81							2/2/81				2/3/81			
SITE:	6			13	1			13	16			3			15	3			15
TIME	SO2	NO	NOX	SO2	SO2	NO	NOX	SO2	SO2	NO	NOX	SO2	NO	NOX	SO2	SO2	NO	NOX	SO2
800								0											
815								300											
830								250											0
845								10											0
900								10									0	1	0
915								275									0	1	0
930								300									0	1	0
945								325									0	1	0
1000								150									0	2	0
1015								5								1	0	6	0
1030								0								1	1	3	0
1045								9								1	1	2	0
1100								40								1	1	2	0
1115								0								1	1	2	0
1130	1	3	2	0	3	3	6	0	0	0	0					1	1	3	0
1145	1	0	0	0	3	5	5	0	0	0	0					1	1	2	0
1200	1	1	1	0	3	5	4	0	0	0	0					1	1	2	25
1215	0	0	0	0	2	5	3	0	0	0	0					0	1	2	30
1230	0	0	0	0	NR	CAL	CAL	0	0	0	0	0	1	5	0	1	1	2	10
1245	0	0	0	0	NR	CAL	CAL	0	0	0	0	0	0	2	0	1	1	2	15
1300	0	0	0	0	2	4	4	0	0	0	0	0	0	4	0	1	2	2	10
1315	0	0	0	0	2	4	5	0	0	0	0	0	0	4	0	1	2	3	35
1330	0	0	0	0	2	4	6	0	0	0	0	116	2	11	0	0	2	1	10
1345	0	0	0	20	2	3	4	0	0	0	0	99	1	9	0	0	2	1	15
1400	0	0	0	110	2	3	6	0	0	0	0	32	1	12	0	0	2	1	30
1415	0	0	0	70	2	4	7	0	0	0	0	22	0	7	0	0	2	2	40
1430	0	0	0	30	2	5	7	0	0	0	0	67	0	3	0	0	1	1	10
1445	0	0	0	20	2	4	7	0	0	0	0	7	0	13	0	1	1	1	30
1500	0	0	0	0	2	5	8	0	0	0	0	30	0	6	0	0	1	1	60
1515	0	0	0	10	2	6	9	0	0	0	0	40	0	9	0	0	2	1	5
1530	0	0	0	10	3	6	6	0	0	0	0	38	2	19	0	0	2	1	50
1545	0	0	0	5	3	6	9	0	0	0	0	25	3	20	0	0	1	1	65
1600	0	0	0	0	4	6	9	0	0	0	0				125				30
1615	0	0	0	0	4	6	8	0	0	0	0				90				55
1630	0	0	0	0															40
1645	0	0	0	0															10
1700	0	0	0	0															25
1715	0	0	0	0															10
1730	0	0	0	0															0
1745	0	0	0	70															0
1800																			

(continued)

TABLE 20 (continued)

SCHOLZ AMBIENT SO2 AND NOX CONCENTRATION CONTINUED

DATE:	2/4/81									2/5/81					
SITE:	5			4			16			6			1		
TIME	SO2	NO	NOX	SO2	NO	NOX	SO2	NO	NOX	SO2	NO	NOX	SO2	NO	NOX
800															
815													30		
830							0	0	3				72	37	66
845							0	0	1				100	32	54
900							0	0	0		23	41	46	10	22
915							0	0	0	4	42	61	2	3	10
930							0	0	0	310	58	64	0	3	8
945							0	0	0	158	20	36	0	2	5
1000							0	0	3	222	77	96	CAL	1	8
1015	0	0	0	0	0	0	0	0	2	184	34	44	4	17	32
1030	0	0	0	0	0	0	0	0	3	147	7	15	12	3	8
1045	0	0	0	0	0	0	0	0	0	38	44	62	6	CAL	CAL
1100	0	0	0	0	2	7	0	0	0	193	11	16	7	CAL	CAL
1115	0	0	0	0	1	6	0	0	0	14	3	4	28	6	12
1130	0	0	0	0	1	6	0	0	0	11	1	5	22	4	12
1145	0	0	0	0	1	5	0	0	0	11	1	5	22	3	9
1200	0	CAL	CAL	0	0	0	0	0	0	11	2	5	29	3	11
1215	0	CAL	CAL	0	1	5	0	0	0	11	2	5	36	3	13
1230	CAL	2	5	2	2	7	0	0	0	11	2	5	31	3	10
1245	1	2	5	4	2	7	0	0	0	12	2	5	6	5	7
1300	3	2	6	7	2	7	10	0	5	12	2	4	4	3	7
1315	5	1	8	10	2	7	10	0	10	12	1	4	4	2	4
1330	4	1	9	6	2	7	5	0	10	12	1	4	5	2	4
1345	2	1	9	6	2	7	0	0	5	11	2	4	4	2	3
1400	0	1	8	6	2	7	0	0	0	10	2	4	4	2	3
1415	1	2	9	6	2	7	0	0	0	10	3	4	3	7	11
1430	1	3	9	7	2	7	0	0	0	10	3	4	3	3	3
1445	2	4	8	8	CAL	CAL	0	0	0	10	2	4	2	3	2
1500	3	4	7	CAL	CAL	CAL	0	0	0					3	4
1515				11	1	7	0	0	0					3	5
1530				11	2	7	0	0	3						
1545							0	0	0						
1600							0	0	0						
1615							0	0	20						
1630							0	5	15						
1645							0	3	3						
1700							0	0	0						
1715							0	0	0						
1730							0	0	0						
1745							0	0	0						
1800															

(continued)

TABLE 20 (continued)

SCHOLZ AMBIENT SO2 AND NOX CONCENTRATION CONTINUED

DATE:	2/9/81										2/10/81						
SITE:	1			2			13	16			7 & 8			9			13
TIME	SO2	NO	NOX	SO2	NO	NOX	SO2	SO2	NO	NOX	SO2	NO	NOX	SO2	NO	NOX	SO2
800														427			0
815	169	20					0	0	0	0				427	91	121	0
830	98	7					0	0	0	0				282	57	63	0
845	24	2					0	0	0	0				232	33	53	0
900	4	2					0	0	0	0				92	44	95	0
915	1	2					0	0	0	0				134	78	111	0
930	NR	NR	NR				0	0	0	0				200	60	97	0
945	NR	NR	NR				0	0	0	0				258	81	119	0
		NR	NR														
1000	NR	NR	NR		1	5	0	0	0	10				266	70	111	0
1015	NR	NR	NR		0	4	0	15	28	28	63	16	27	342	61	96	0
1030	NR	NR	NR		0	5	0	20	40	80	79	14	41	309	72	103	0
1045	NR	NR	NR	6	0	5	0	50	90	275	23	6	13	205	46	82	0
		NR	NR														
1100	NR	NR	NR	6	0	4	0	15	35	250	9	5	8	229	34	36	0
1115	3	3		6	0	4	0	0	0	10	1	2	0	62	0	8	0
1130	3	2		6	0	4	0	0	0	0	0	1	1	0	3	23	0
1145	3	2		6	0	3	0	0	0	0	1	1	2	67	13	23	0
1200	CAL	1		6	0	5	0	0	0	0	4	1	3	53	2	3	0
1215	CAL	1		6	0	3	0	0	0	0	2	2	4	4	CAL	CAL	0
1230	8	2		7	0	3	0	0	0	0	NR	NR	NR	CAL	CAL	CAL	0
1245	5	0		7	0	3	0	0	0	0	31	3	15	CAL	CAL	CAL	0
			6	4													
1300	9	24		7	0	4	0	0	0	0	16	5	13	2	0	4	0
1315	16	3		6	0	4	0	0	0	0	39	3	16	3	0	4	0
1330	6	CAL	CAL	6	0	4	100	0	0	0	45	4	19	3	0	7	0
1345	4	CAL	CAL	6	0	3	120	0	0	0	41	3	15	110	32	72	0
1400	1	CAL	CAL	7	0	2	140	0	0	0	9	1	5	271	66	100	0
1415	8	CAL	CAL	6	0	3	125	0	0	0	6	5	9	386	41	78	0
1430	7	CAL	CAL	8	0	4	50	0	0	5	16	3	7	206	19	45	0
1445	1	9		32	0	10	20	0	0	0	32	3	12	230	16	36	0
1500	1	14		7	0	4	0	0	5	10	44	3	13	226	10	23	0
1515	1	12		7	3	7	0	0	10	15	38	3	11	110	23	46	0
1530	1	12		7	1	5	0	0	3	20	25	2	8	189	36	65	0
1545	1	12		23	13	25	0	0	0	0	13	2	3	313	24	47	0
1600	2	13		11	3	7	0	0	0	0	16	1	4	242	32	60	0
1615	3	15			2	7	0	0	0	0	25	2	7	252	58	86	0
1630	2	15					0	0	0	0	11	1	3	343	54	82	0
1645							0	0	0	0	5	2	2	374	39	66	0
1700														316			0
1715														209			0
1730																	
1745																	
1800																	

(continued)

TABLE 20 (continued)

SCHOLZ AMBIENT SO2 AND NOX CONCENTRATIONS CONTINUED

DATE:	2/11/81				2/12/81						2/13/81					
SITE:	3			15	10			11			11			12		
TIME	SO2	NO	NOX	SO2	SO2	NO	NOX	SO2	NO	NOX	SO2	NO	NOX	SO2	NO	NOX
800																
815														263	80	42
830														219	76	131
845														132	50	63
900														320	156	126
915					7	5	11							200	84	125
930					7	5	12							264	150	143
945					6	5	9							247	164	77
1000					6	4	9				70	22	27	239	136	76
1015					7	4	12				46	21	20	304	142	17
1030					7	4	9				NR	25	33	149	65	113
1045					6	5	7				94	25	32	232	37	57
1100					6	5	13				187	CAL	4	189	153	5
1115					5	5	7				203	CAL	CAL	36	25	22
1130					5	4	6				114	3	10	118	36	29
1145		13	20	0	5	4	6				40	2	9	17	24	31
1200	0	13	20	90	6	4	5	0			100	24	42	14	85	2
1215	0	17	245	5	6	4	11	45			230	24	40	13	CAL	CAL
1230	11	CAL	CAL	85	6	4	7	5			9	1	5	10	CAL	CAL
1245	12	CAL	CAL	3	6	4	7	19			13	0	6	9	CAL	3
1300	40	CAL	CAL	2	6	3	6	47			11	0	7	85	14	14
1315	95	10	7	25	6	3	6	83			NR	1	5	101	29	4
1330	4	8	15	160	6	2	6	139	12	16	NR	2	6	92	15	15
1345	9	0	4	30	6	2	5	17	24	20	NR	2	0	75	30	14
1400	30	1	5	15	6	4	7	43	3	5	NR	2	6	100	56	63
1415	0	3	6	90	6	2	5	2	4	7	NR	1	7	282	64	99
1430	2	3	5	75	6	5	7	40	3	3	NR	0	7	145	96	23
1445	1	2	3	25	6	3	5	6	7	13	73	3	16	115	34	22
1500	1	1	3	60	6	2	5	65	4	8	95	0	9		40	15
1515	2	1	3	90	6	3	5	52	5	10	340	32	62			
1530	3	0	2	20	6	3	5	3	6	12	333	24	60			
1545	2	2	2	130	6	3	4	20	2	5	43	4	16			
1600	1	0	1	100	5	3	5	72	3	10	89	5	21			
1615	0	0	0	70				6	7	13	159	7	32			
1630	0	0	8	80				46	3	4	132	9	26			
1645	2	0	0	30				73	7	23	57	0	15			
1700				45					8	23						
1715				30					7	22						
1730				3												
1745				0												
1800																

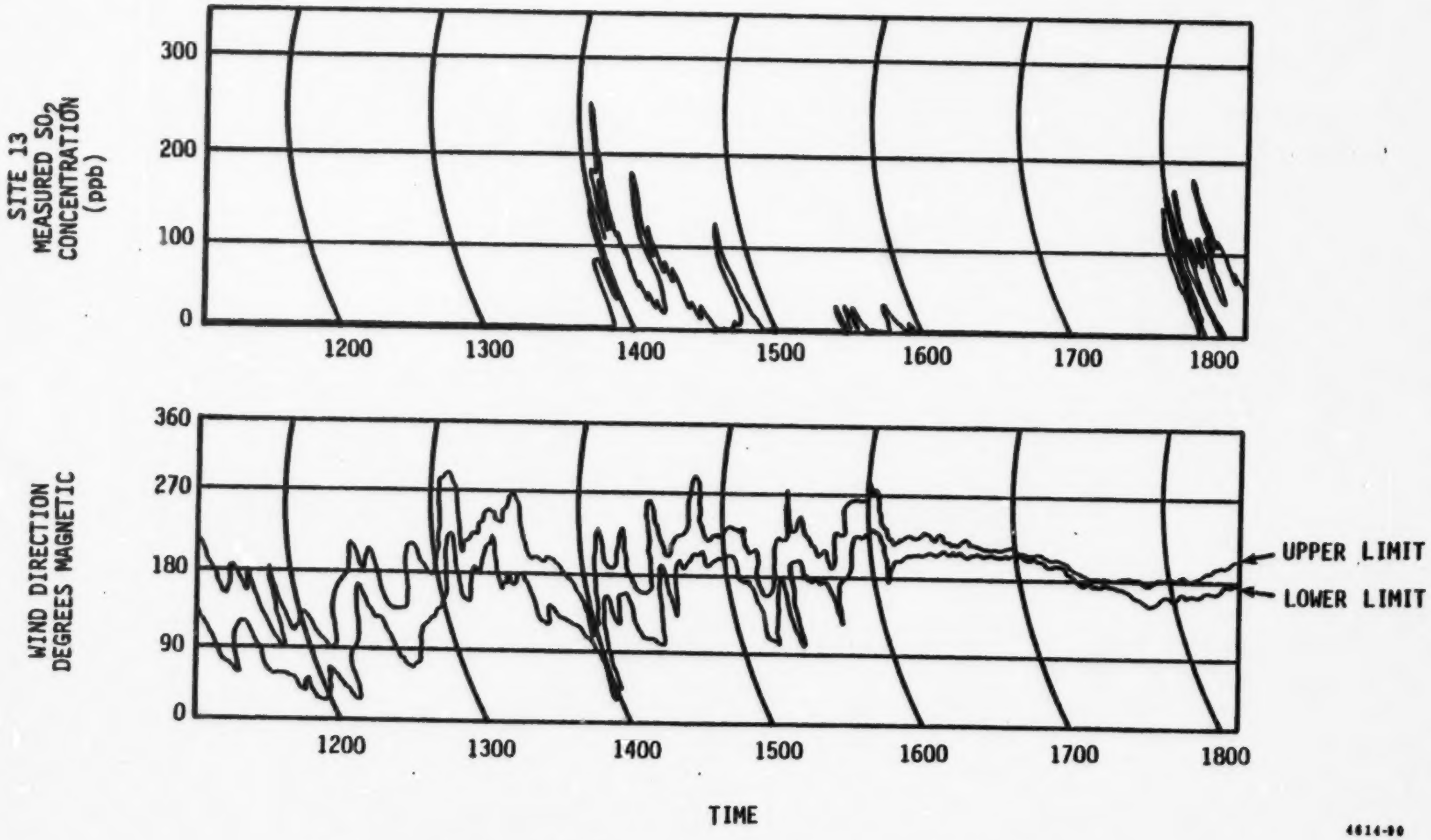

Figure 22. Wind direction (200 ft level) and measured SO_2 concentration at Site 13 on January 29, 1981.

Test 2 - 1/30/81

The center of the high pressure system moved to the southwest of Chattahoochee and a low pressure system approached from the west. Wind flow was stronger than on January 29, with velocities ranging from 5 to 15 mph as measured at the 200 ft level of the meteorological tower. Winds were out of the south-southwest during the morning hours, but became more westerly in the afternoon. Skies were clear in the morning, but clouds moved in from the northwest about noon.

Air quality was monitored at sites 1, 13, and 16. Sites 1 and 16 were not affected by emissions from the plant and were representative of background conditions. Plume strikes were noted in the SO_2 data for site 13 in the morning but not in the afternoon as a result of a wind shift from southerly to westerly. Background concentrations for SO_2 and NO_x were observed to be in the range of 5-10 ppb at site 1 and near zero at site 16.

Figure 23 illustrates the observed SO_2 concentrations at site 13. The highest concentrations were observed when the wind direction was from slightly east of due south. The SO_2 concentrations at this location were frequently off-scale (>500 ppb) between the hours of 0800 and 1000. The expected wind direction for peak concentrations at this site was 192 degrees. The fact that the actual peak concentrations occurred when the wind was slightly east of south may have resulted from wind deflection by local topography.

Test 3 - 2/2/81

The forecast for this day called for northwesterly winds (310-330°) at 10-15 mph. The skies were clear for the entire sampling period. The locations selected for monitoring on this date were sites 3, 15, and 16. Site 16 is located approximately 2 km west of the plant and was used to describe the background conditions. Site 15 is one of the fixed monitoring stations maintained by Gulf Power. All parameters except NO_x were monitored at this site.

Background SO_2 and NO_x concentrations were essentially zero at all sites. Plume strikes were noted at site 3 between 1330 and 1600 hours and strikes were noted at site 15 after 1600 hours. Figure 24 illustrates the observed SO_2 and NO_x concentrations at sites 3 and 15. The figure shows that a shift in wind direction from west-northwest to northwest resulted in the plume passing to the south of site 3. The maximum SO_2 and NO_x concentrations at site 3 were 300 and 70 ppb, respectively. The highest SO_2 concentration at site 15 was 260 ppb.

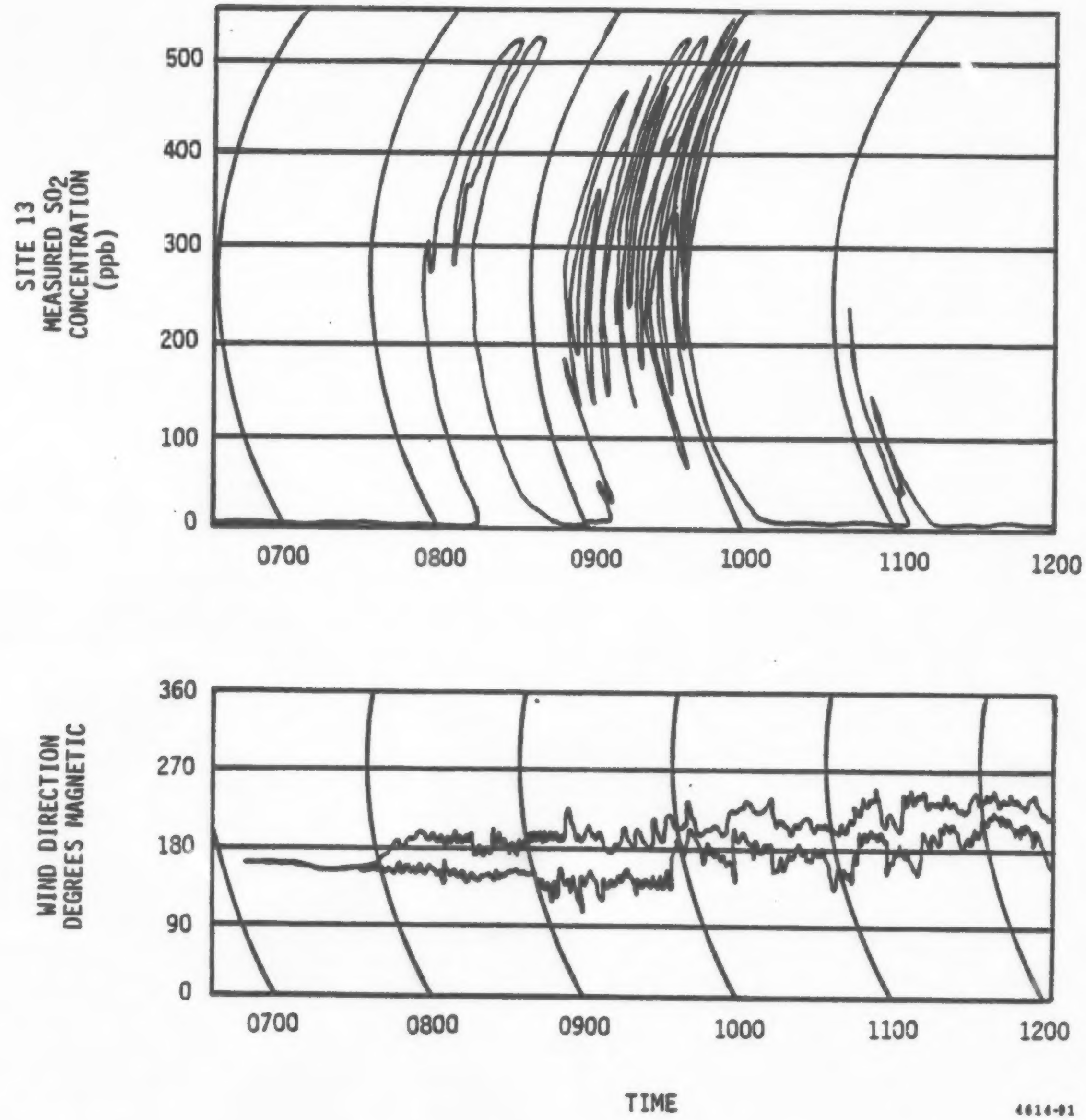

Figure 23. Wind direction (200 ft level) and measured SO_2 concentration at Site 13 on January 30, 1981.

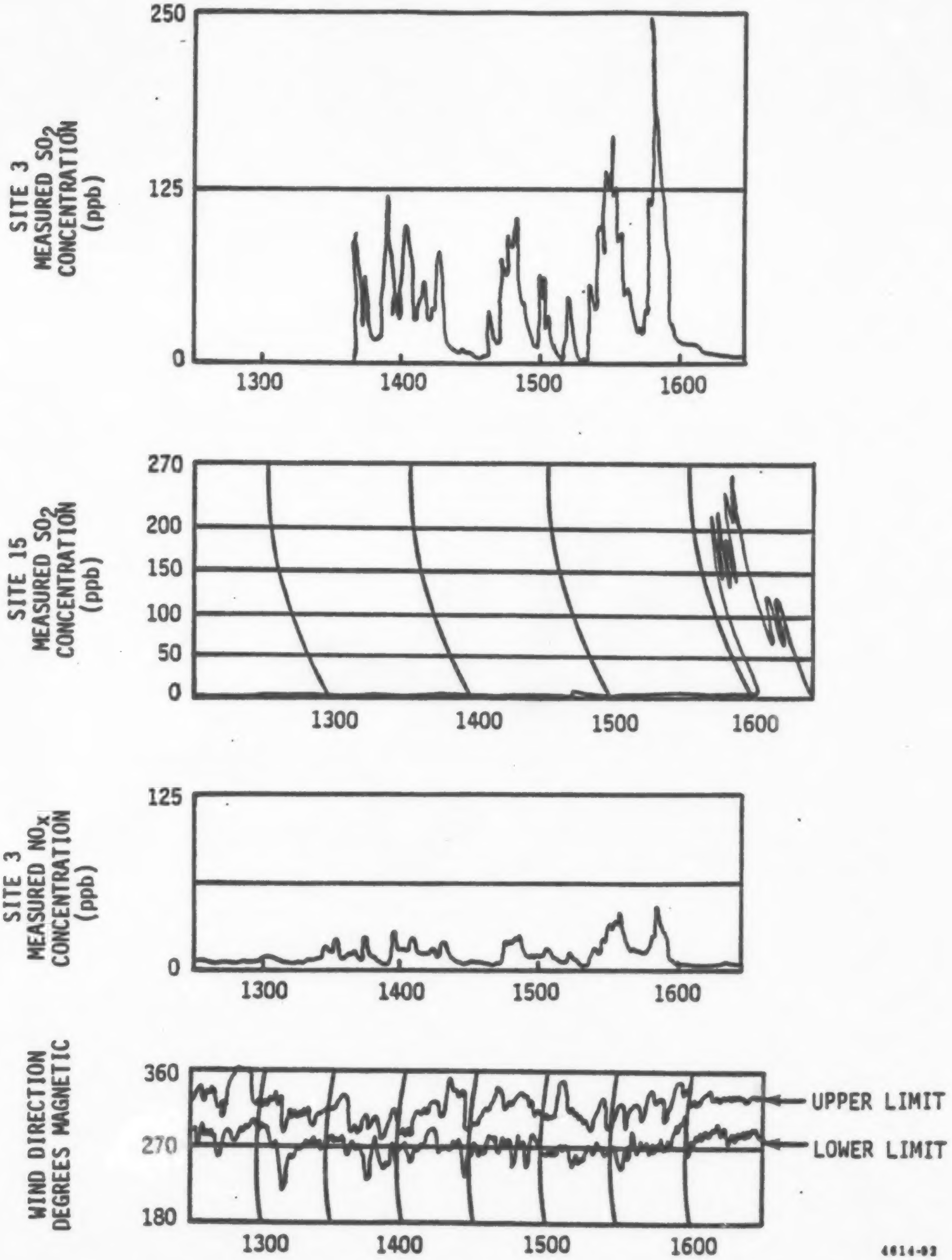

Figure 24. Wind direction (200 ft level), measured NO$_x$ concentration at Site 3 and measured SO$_2$ concentration at Sites 3 and 14 on February 2, 1981.

Test 4 - 2/3/81

A high pressure system approached the area from the west and winds were forecast to be from the northwest at 10-15 mph. The skies were clear for the entire sampling period. The locations selected for monitoring were again sites 3, 15, and 16 with site 16 serving as a nominal up-wind location. Background concentrations were essentially zero for SO_2 and NO_x from 0730 to 1700 hours; concentrations of about 10 ppb were noted between 1700 and 1730 hours. The TSP concentration at site 16 was below detection limits per EPA quality assurance criteria. On this date the plume passed south of site 3 but was recorded at site 15. Winds were more northerly than on February 2, accounting for the absence of plume strikes at site 3. Figure 25 indicates that the wind oscillated between 270 and 360 degrees. As the plume meandered across the Appalachicola River valley, it occasionally impacted site 15. The peak SO_2 concentration at site 15 was 225 ppb.

Test 5 - 2/4/81

The forecast for this date called for northerly winds at 10-15 mph, becoming light and variable in the afternoon. Skies were clear in the morning; however, cloudiness increased through the day and by mid-afternoon the cloud cover was about 80%. The pilot balloon launches indicated that there was no temperature inversion and the lapse rate was close to adiabatic.

The locations selected for monitoring sites were 4, 5, and 16. Site 16 was used as a nominal upwind location. Sites 4 and 5 are located on an unpaved road situated to the east of the Appalachicola River and south of I-10. Although northerly winds were forecast for the day, the winds persisted from the west. Frequent discussions with the National Weather Service indicated that the winds should have shifted to the north during the day; however, they did not. As a result, no data were collected in the plume.

Test 6 - 2/5/81

Winds on this date were from the north-northwest. Skies were clear in the morning; however, they became progressively more cloudly over the course of the day. By 0900 hours, the cloud cover was about 35% and by 1400 hours it was approximately 90%. The locations selected for sampling on this day were 1, 6, and 13; with 13 serving as the upwind location. Background SO_2 concentrations were essentially zero.

During the morning hours the wind was out of the east, shifting around to the north between 0900 and 1100. The plume was monitored at site 6 between 0900 and 1100 after which it

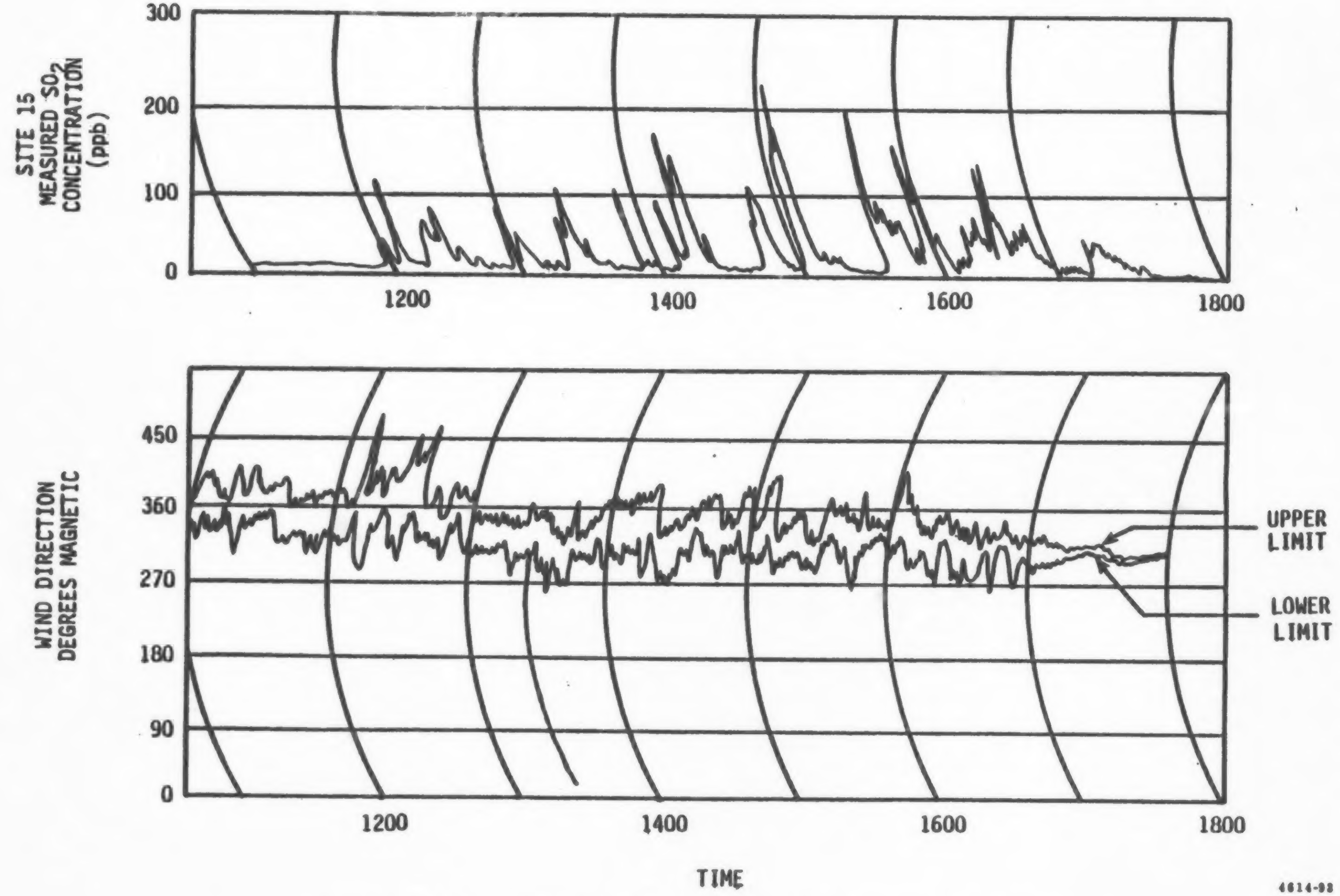

Figure 25. Wind direction (200 ft level) and measured SO_2 concentrations at Site 15 on February 3, 1981.

disappeared from the traces. Plume impact was noted at site 1 until approximately 1300 hours. During the afternoon hours the plume was moving down the Appalachicola River Valley where there were no possible monitoring locations. Figures 26 and 27 illustrate the measured values at sites 1 and 6, respectively, together with the wind direction recorded at the 200 ft level at the meteorological tower. The maximum concentration at site 1 was 500 ppb while numerous spikes over 500 ppb (the maximum concentration measurable with the analyzer) were noted at site 6.

Test 7 - 2/9/81

Winds from the east were forecast for this day. During the morning hours winds were out of the east but they shifted to the north by noon. By late afternoon they had shifted back to the east and then the southeast. The skies were partly cloudy all day, with cloud cover ranging from 20 to 50%.

Sites 1, 2, 13, 14, and 16 were used for monitoring locations. Only sites 1 and 16 were equipped with hi-vol samplers and the plume was observed at both of these locations. Data from site 14 were reviewed for background levels of SO_2 and NO_x; both of which were essentially zero. The plume impacts on sites 13 and 16 are illustrated graphically in Figure 28.

Test 8 - 2/10/81

Winds on this date were out of the south-southwest and wind speeds were strong and gusting throughout the day. The forecast called for rain, however, only intermittent sprinkles occurred. The cloud cover was 100% all day with a low ceiling, therefore no pilot balloon launches were made.

The locations selected for monitoring were sites 7-8, 9, and 13. All four sites were impacted by plant emissions. Data from site 15 was reviewed to characterize background concentrations of SO_2 , which were found to be essentially zero. One of the mobile stations was originally situated at location 7 and was moved to site 8 at 1230 hours after a windshift had moved the plume away from site 7. The plume impacted site 9 virtually all day. Figure 29 graphically illustrates the SO_2 and NO_x concentrations at site 9 through the day. The peak NO_x concentration at site 9 was 175 ppb while the SO_2 concentration frequently went off-scale (>500 ppb). The spikes above 500 ppb are indicated by the marks at the top border of the figure. The traces shown represent "eyeball" averages of the data, as the actual concentrations were fluctuating wildly.

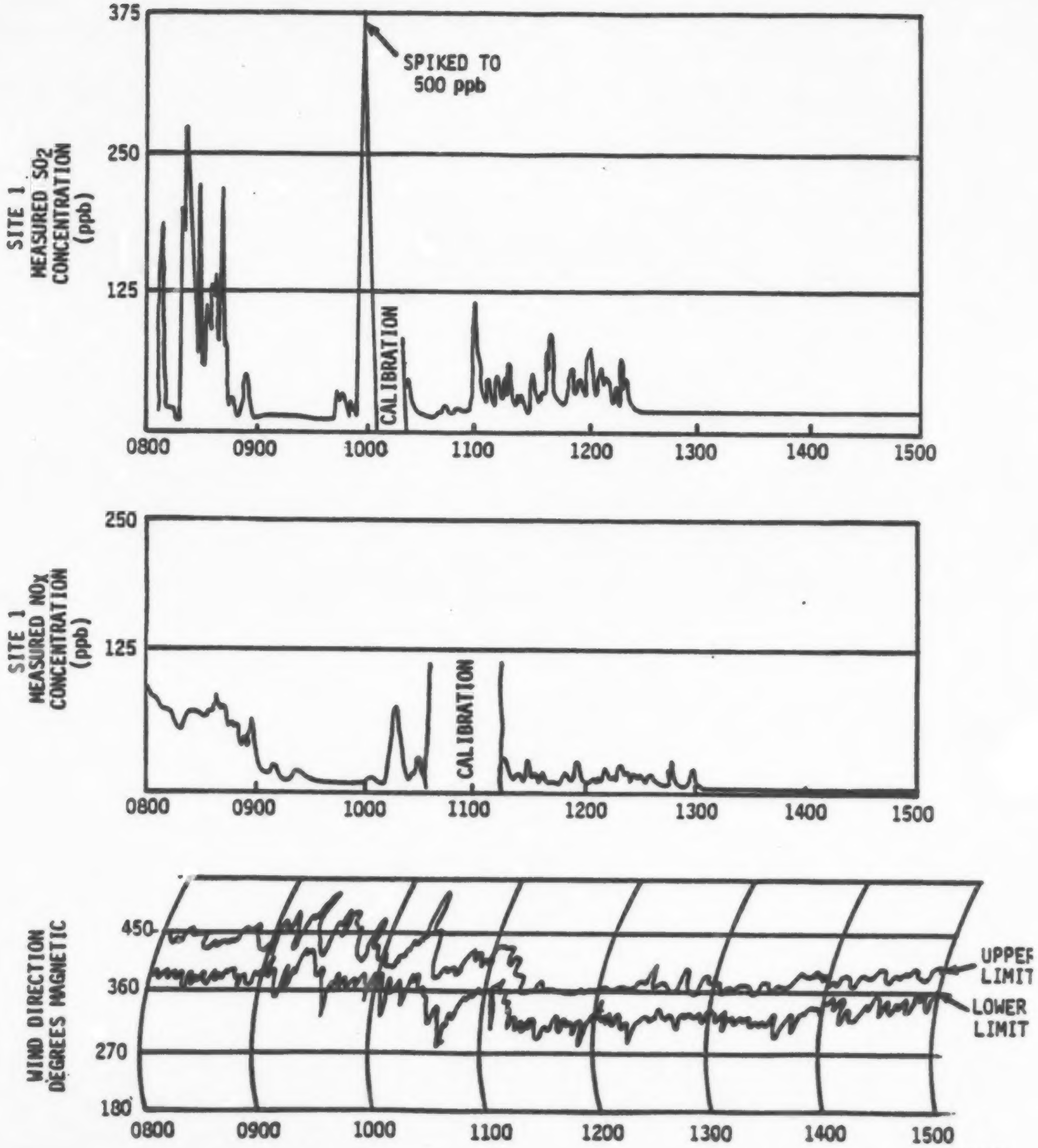

Figure 26. Wind direction (200 ft level), measured NO_x concentration measured SO_2 concentration at Site 1 on February 5, 1981.

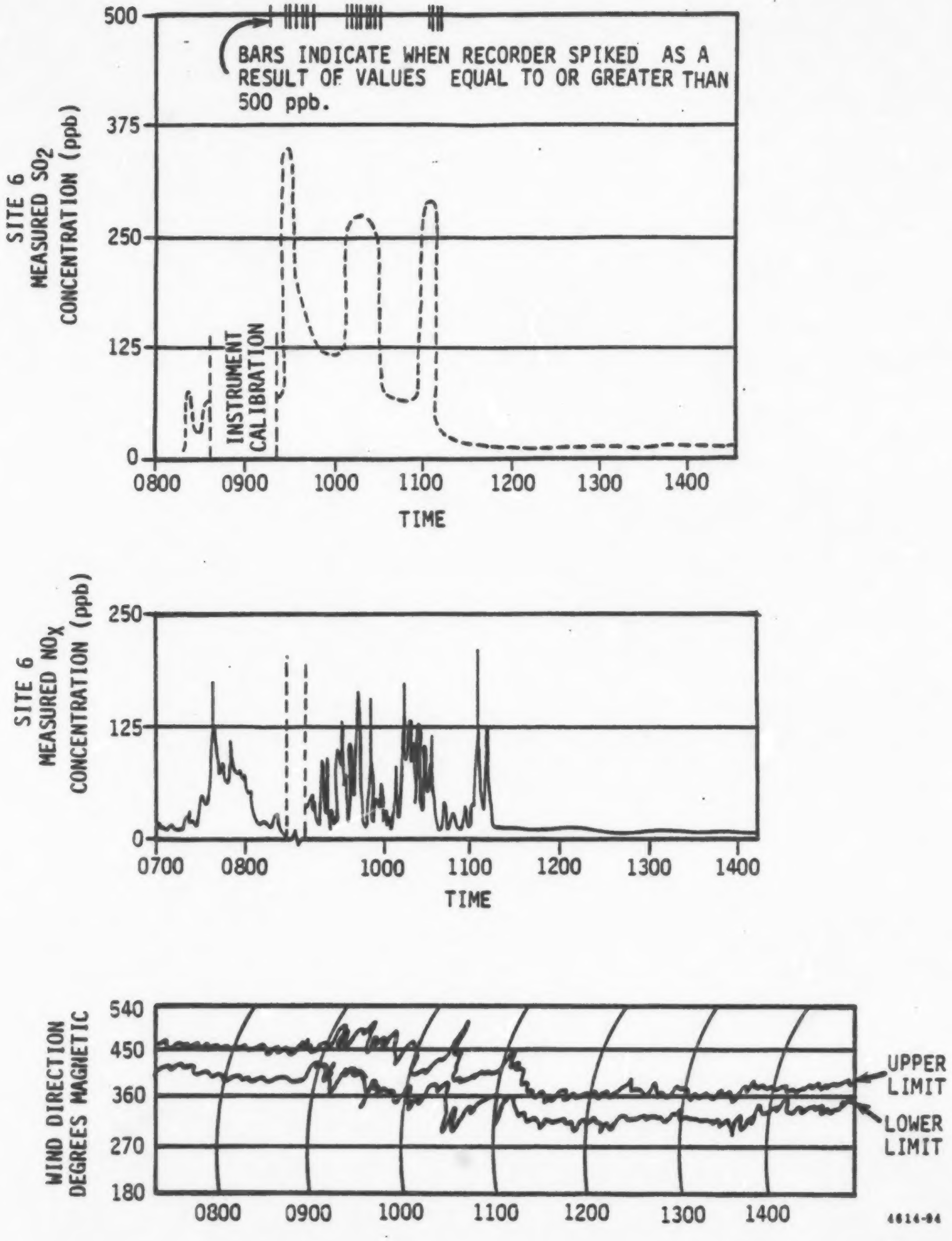

Figure 27. Wind direction (200 ft level), measured NO_x concentration and measured SO_2 concentration at Site 6 on February 5, 1981.

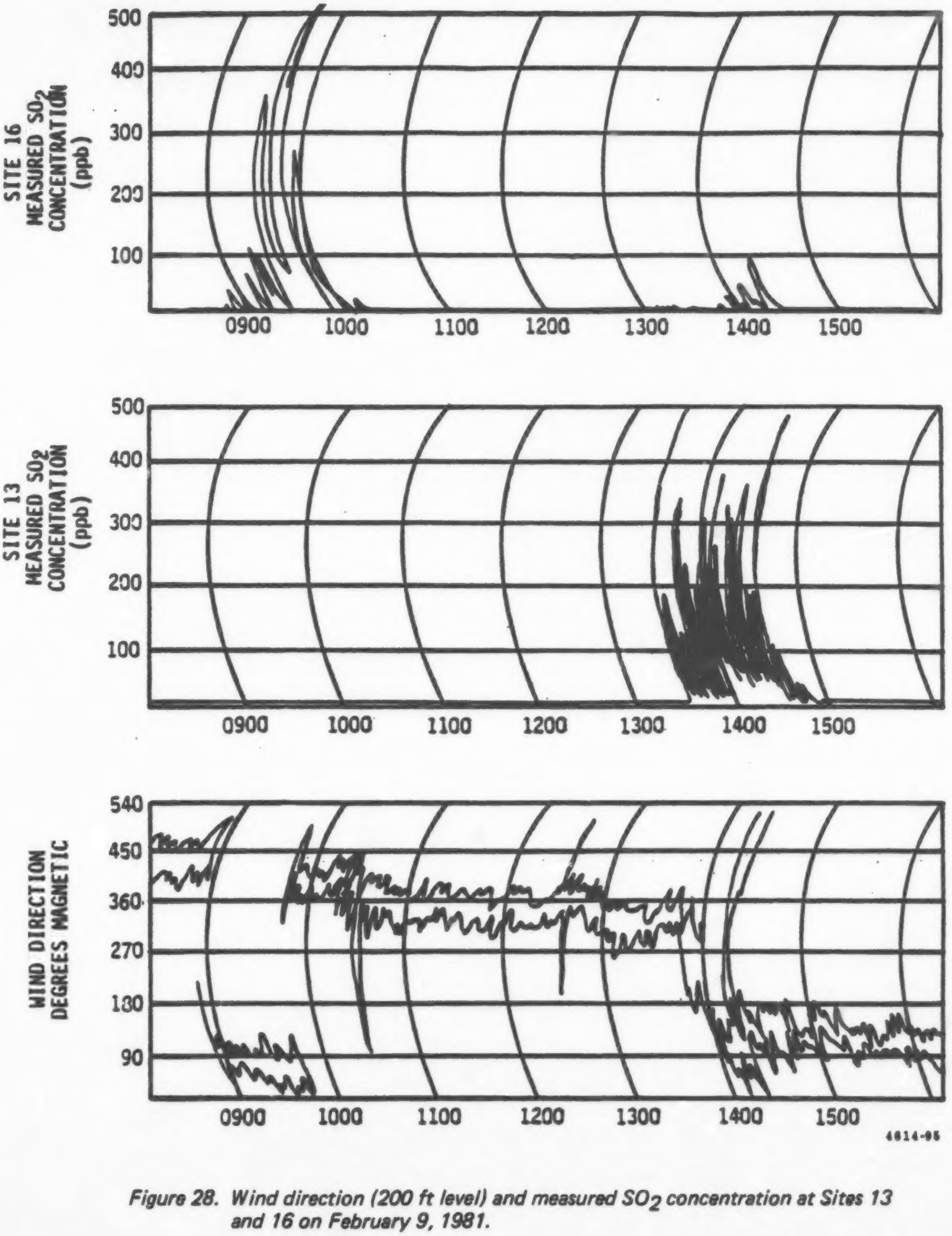

Figure 28. Wind direction (200 ft level) and measured SO_2 concentration at Sites 13 and 16 on February 9, 1981.

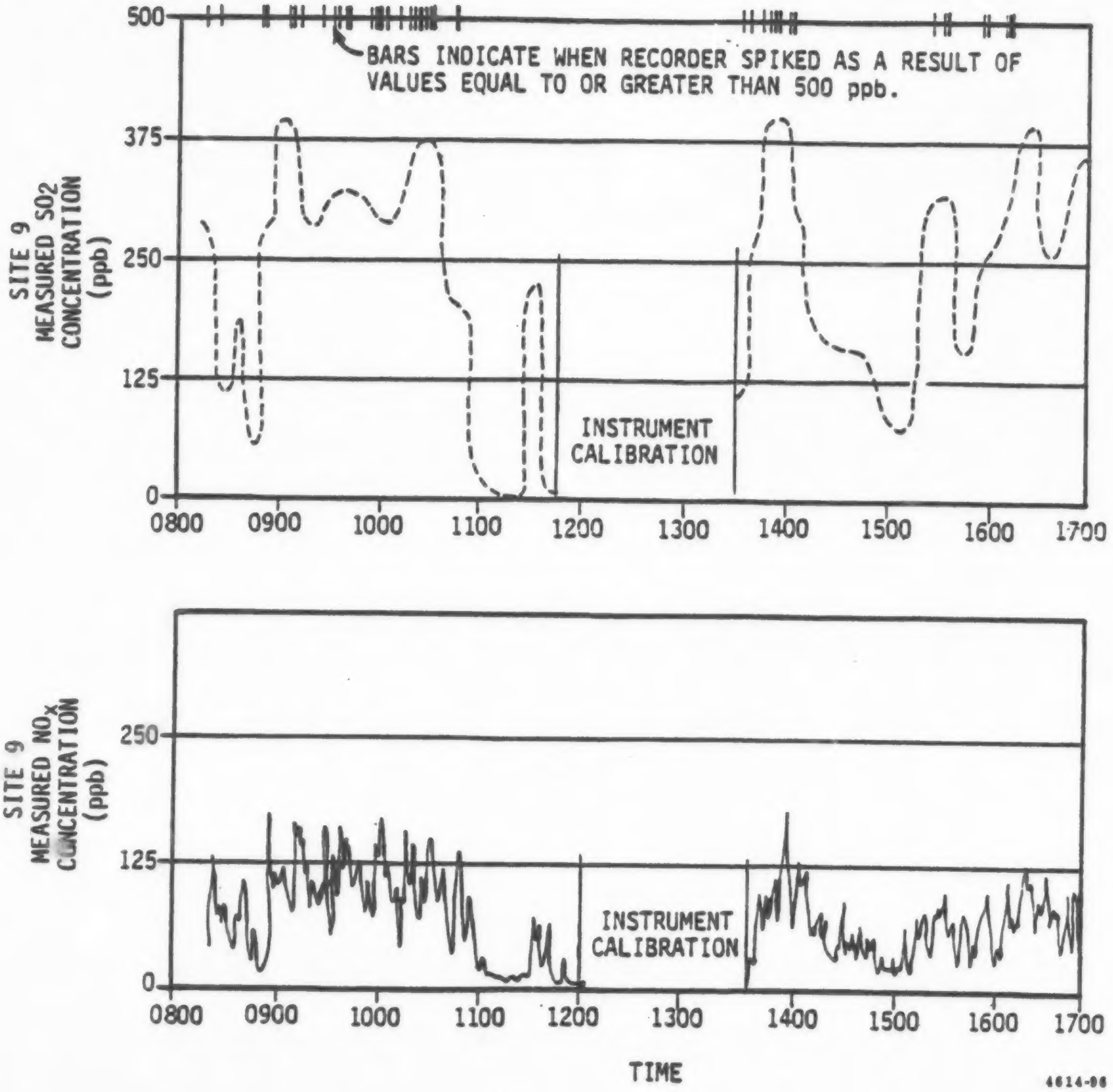

Figure 29. Measured SO_2 and NO_x concentrations at Site 9 on February 10, 1981.

Test 9 - 2/11/81

On this date the winds forecast to be out of the west-northwest. In the morning the sky was completely overcast. By 1300 hours the cloud cover had decreased to 75%, and by 1400 hours the skies were clear. Monitoring sites for the day were 3, 13, and 15. Background concentrations of SO_2 and NO_x were zero throughout the day. The observed concentrations indicate that the plume impacted site 3 between 1230 and 1430 hours and site 15 between 1200 and 1800 hours.

Test 10 - 1/12/81

Winds of 10-15 mph from the north-northwest were forecast for the day. Skies were clear for the entire sampling period. Sites 10, 11, and 15 were selected as sampling locations. Winds remained out of the northeast for the duration of the day and site 15 was used as a nominal upwind location. SO_2 and NO_x concentrations at this site were zero throughout the day. The plume did not impact site 10 and the (low) concentrations of SO_2 and NO_x that were observed at this site are attributed to vehicular traffic on I10. The plume did impact site 11 between 1200 hours and 1700 hours.

Test 11 - 2/13/81

East-northeast winds were forecast for this date with mostly overcast skies. Sites 3, 11, and 12 were selected as sampling locations with site 3 serving as the location for determining background concentrations. Again, background concentrations of SO_2 and NO_x were essentially zero. On this date the plume was observed at both sites 11 and 12 between 0800 and 1700 hours.

H_2SO_4 Measurements

The H_2SO_4 samplers were completed just before departure for the test and were not fully checked out when shipped. Numerous problems occurred with these systems during the first two weeks of the test. The cause of the problems was finally traced to a faulty batch of thermocouple connectors in the temperature control circuits. A few days of data were eventually obtained after replacing the faulty connectors. The H_2SO_4 results shown in Table 18 represent time weighted averages of the samples taken at the indicated location during each day. The results of the individual runs are given in Table 21. These results indicate that between 40 and 95 percent of the particulate sulfate smaller than 3 μm sampled by the systems was in the form of H_2SO_4. Because of the numerous problems that occurred during the early portions of the test, the sampler operations, once the equipment was debugged, were concentrated on collecting data in the plume. Therefore the ambient H_2SO_4 data are highly biased

TABLE 21. RESULTS FROM THE CHEMICAL ANALYSES OF AMBIENT SULFURIC ACID SAMPLES

System #	Run #	Date	Sample Duration (Min)	Sample Location	Prefilter SO_4^{2-} ($\mu g/m^3$)	H_2SO_4 ($\mu g/m^3$)	Total SO_4^{2-} ($\mu g/m^3$)
1	1	1/9/81	105	2	0.6	4.3	4.8
	2	1/9/81	104	2	2.6	5.1	7.6
	3	1/10/81	88	7	3.0	7.7	10.5
	4	1/10/81	75	7	7.7	9.6	17.1
	5	1/11/81	55	12	2.8	5.8	8.5
	6	1/11/81	75	12	2.9	6.1	8.9
	1	1/9/81	74	1	2.9	5.2	8.0
	2	1/9/81	72	1	2.4	2.2	4.6
	3	1/10/81	65	9	1.2	33.0	33.5
	4	1/10/81	30	9	14.6	21.0	35.2
	5	1/10/81	48	9	13.3	10.5	23.6
	6	1/10/81	30	9	4.3	38.8	42.4
	7	1/10/81	62	9	1.5	4.0	5.4
	8	1/10/81	41	9	3.2	16.9	19.8
	9	1/10/81	46	9	2.4	13.2	15.3
	10	1/11/81	65	3	1.5	4.5	5.9
	11	1/11/81	65	3	4.3	8.0	12.1
	12	1/11/81	51	3	2.3	4.7	6.9

Remarks: These are the ambient sulfuric acid (<3 μm) and total sulfate (<3 μm) concentrations determiend from analysis of samples collected with the SoRI Sulfuric acid samplers. Total sulfate was calculated as the amount found on the prefilter plus the sulfate fraction ($\frac{96}{98}$) of the sulfuric acid found.

toward in plume samples and are not representative of average conditions; however, the data do indicate that the plant's contribution to the local, ambient sulfate levels is about 90 to 95% H_2SO_4 - a not too surprising result.

Particle Size Distribution

Particle size distribution measurements were attempted in two ways. First, the hi-vol samplers used to obtain TSP concentrations were fitted with Sierra Model 234 Hi-vol Impactor heads which provide size classification cuts at 7.2, 3, 1.5, and 0.95 μm (aerodynamic diameter basis). Second, Lundgren cascade impactors were run to obtain samples for the determination of elemental concentrations versus particle size. Neither technique was notably successful because the ambient particulate concentrations actually encountered were much lower than were anticipated.

In the case of the hi-vol impactors, only the backup filter weight gains were above detection limits for most runs. The TSP values quoted are based on these filter weights in most cases. Data were obtained from all stages on 2/10. On this date a composite of the three samples indicated the distribution was approximately log-normal with a mass median diameter of about 0.65 μm and a sigma-g of 7.5. However, the true distribution was probably bimodal with an unresolved sub-micron component as will be discussed in the following paragraphs. Figure 30 illustrates the measured distributions from the three individual runs together with the composite distribution.

The substrates and filters from the Lundgren impactor runs were analyzed by XRF and NAA with the intent of obtaining elemental composition by size for comparison with the Scholz Plant emission signature previously discussed. However, the stage loadings were so light that, with the exception of sulfur, the results were all essentially in the "noise" of the determinations. Possibly valid data were obtained for the elements Al, V, Zr, and Ba in addition to the good results for sulfur. In the case of the former four elements, the concentrations of each in the size range collected by the backup filter was zero, while moderate to high concentrations of sulfur were found on the backup filters. The sulfur concentration dropped rapidly toward the larger sizes, while the concentrations of the other four elements detected did not. Size distributions for sulfur, shown in Figure 31, revealed mass median diameters for the sulfur distributions ranging from about 0.25 μm to 1 μm; with an average value of 0.55 μm. The elements Al, V, Zr, and Ba revealed distributions having a mass median diameter of about 3.5 μm as shown in Figure 32, a value considerably larger than that found for sulfur. The data thus show the net ambient aerosol to be

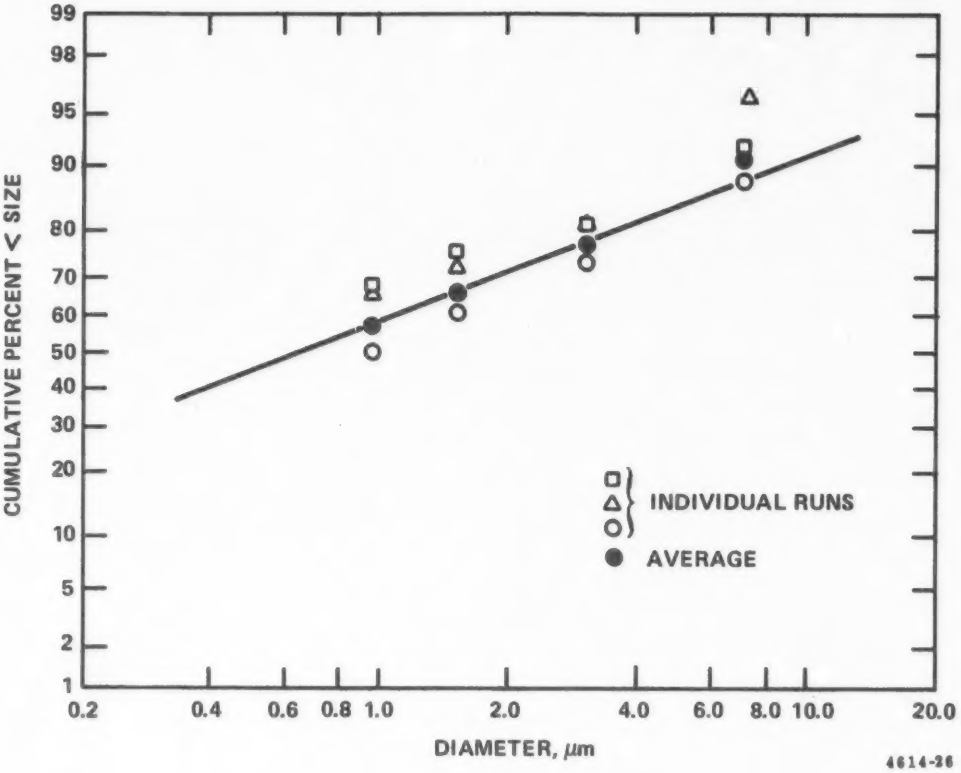

Figure 30. Ambient air size distributions from Sierra HI-VOL Impactors.

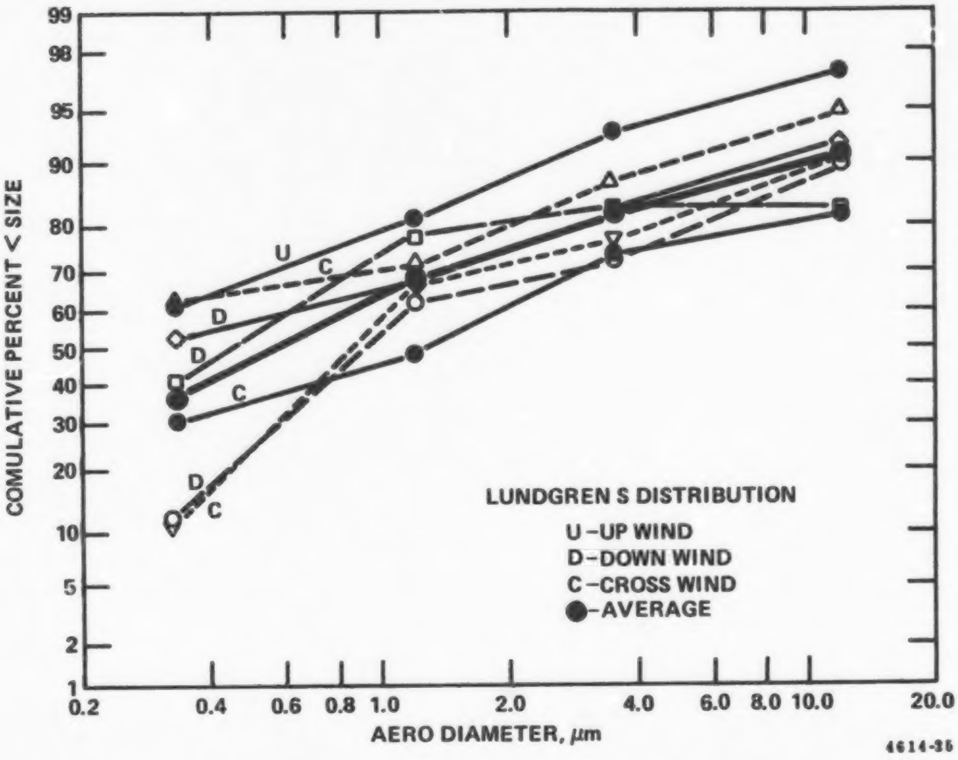

Figure 31. Ambient sulfur distribution by particle size from Lundgren Impactors.

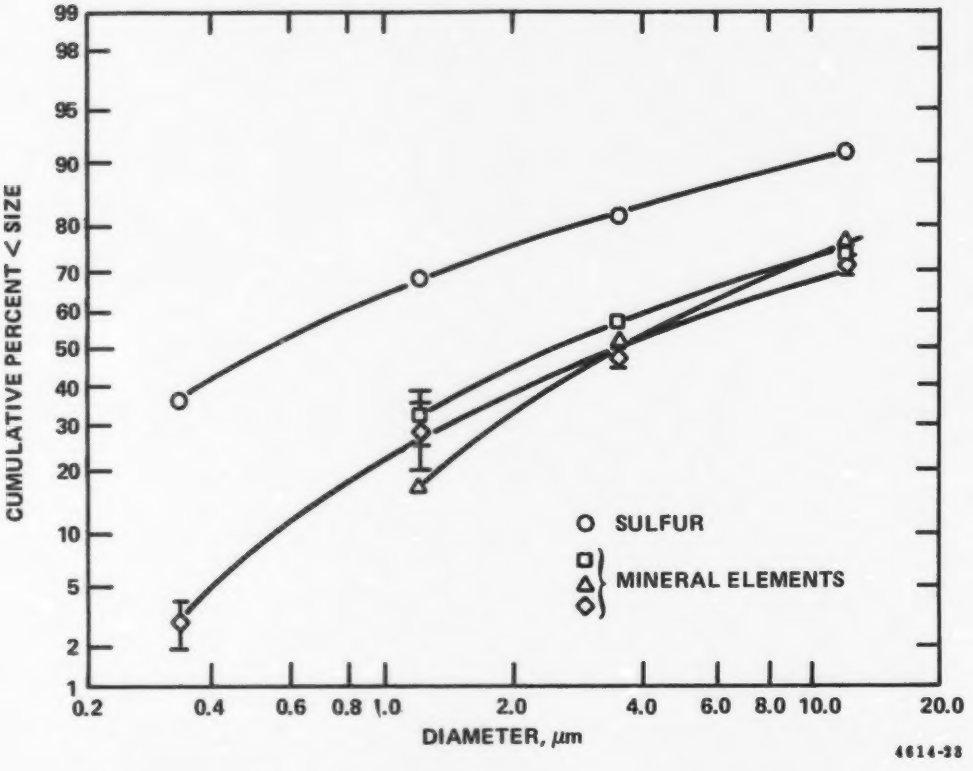

Figure 32. Comparison of sulfur and mineral element distributions from Lundgren Impactors.

comprised of two modes, one a submicron mode typified by sulfur and perhaps containing other "condensible" species; and a second, supermicron mode typified by more refractory mineral elements.

The mean sizes and other distribution parameters given in the preceding paragraphs are subject to large uncertainties because of the very low stage catches. Because of these uncertainties they should not be taken as much more than qualitative indicators of trends.

Elemental Analyses of Hi-vol Filters

As originally planned, elemental analyses were only to be done on the Lundgren impactor samples; but when it became apparent that the impactor data were not going to be suitable for quantifying the portions of the ambient particulate matter contributed by the plant a decision was made to perform analyses of the teflon hi-vol filters. On the whole, the surface density of material on the hi-vol filters would be expected to be about five fold greater than the particulate density on the surface of the Lundgren stages; thus the detectability of many elements would be considerably better. Thirty-nine elements were detected on some or all of the teflon filters by the combination of XRF and NAA techniques. Many of these were found only on a few of the filters and then only near the detection limits; however, twenty-six of the thirty-nine were detected on most or all of the filters at high enough concentrations to be useful in particulate source identification.

The concentrations of the detected elements and the uncertainties in the concentrations are given in Tables 22 and 23. The uncertainties quoted include both measurement uncertainties quoted by the analytical laboratories and estimates of the uncertainties in the gas volumes sampled by each filter. Other data associated with each filter sample can be found in Table 18 using the filter identification number as a key.

In addition to the analyses of the hi-vol filters, soil samples from four of the ambient sampling sites were submitted for neutron activation analysis. Only the fine fraction of the bulk soil samples, after separation by means of a Bahco Microparticle Classifier, was analyzed. This fraction contained particles in the 1.5 to 8 μm size range, corresponding to the range in which the impactor data indicated that most of the mineral elements in the ambient samples were found. The results of these analyses are given in Table 24. Note that while the composition of the samples are fairly uniform for most elements, there are large differences among them for a few elements. These differences were later used in accessing the reasonableness of results of a reconstruction of the ambient filter data by factor analysis.

TABLE 22. RESULTS OF X-RAY FLUORESCENCE AND NEUTRON ACTIVATION ANALYSES OF TEFLON MEMBRANE HI-VOL FILTERS

ORIGINAL DATA MATRIX

		1 36005	2 36007	3 36008	4 36009	5 36010	6 36011	7 36012	8 36013	9 36014
AL	1	0.4297E+00	0.7104E+00	0.3782E+00	0.1105E+01	0.4019E+00	0.3691E+00	0.6406E+00	0.1168E+01	0.7561E+00
Si	2	0.1049E+01	0.2051E+01	0.2623E+00	0.1564E+01	0.7286E+00	0.1155E+01	0.1277E+01	0.9967E+00	0.1476E+01
P	3	0.2891E-01	0.2231E-01	0.8092E-01	0.2328E-01	0.1071E+00	0.0000E+00	0.1030E+00	0.0000E+00	0.6483E-01
S	4	0.1034E+01	0.9794E+00	0.6083E+00	0.9285E+00	0.8920E+00	0.4012E+00	0.4862E+00	0.5764E+00	0.6804E+00
Cl	5	0.3281E+00	0.1726E+00	0.1217E+00	0.1169E+00	0.3486E-01	0.3117E-01	0.7132E-01	0.1573E+00	0.7252E-01
K	6	0.1373E+00	0.1031E+00	0.2511E-01	0.8441E-01	0.4857E-01	0.2632E-01	0.7153E-01	0.8389E-01	0.1207E+00
Ca	7	0.1614E+00	0.1442E+00	0.2455E-01	0.2011E+00	0.1159E+00	0.1059E+00	0.1567E+00	0.2068E+00	0.1297E+00
Ti	8	0.5232E-01	0.1050E+00	0.0000E+00	0.3064E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2182E-01
V	9	0.1908E-02	0.2053E-02	0.3445E-02	0.1801E-02	0.7152E-03	0.7700E-03	0.1226E-02	0.6381E-02	0.2342E-02
Cr	10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Mn	11	0.6912E-02	0.8332E-02	0.2196E-03	0.5590E-02	0.4569E-02	0.4128E-02	0.8463E-02	0.1009E-01	0.8687E-02
Fe	12	0.2929E+00	0.4809E+00	0.5022E-01	0.5462E+00	0.1921E+00	0.3004E+00	0.2393E+00	0.2625E+00	0.4698E+00
Co	13	0.5135E-04	0.1188E-03	0.0000E+00	0.6208E-02	0.5618E-04	0.2039E-03	0.5954E-04	0.0000E+00	0.1766E-04
Ni	14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1766E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Cu	15	0.3980E+00	0.9840E-01	0.6473E+00	0.6703E+00	0.2903E+00	0.1688E+00	0.3193E+00	0.6437E+00	0.7061E+00
Zn	16	0.3329E-01	0.2159E-01	0.0000E+00	0.1736E+00	0.3042E-01	0.3000E-01	0.3690E-01	0.2976E-01	0.1743E-01
Ga	17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
As	18	0.0000E+00	0.0000E+00	0.0000E+00	0.6228E-02	0.2697E-02	0.5331E-03	0.0000E+00	0.2487E-02	0.0000E+00
Se	19	0.1924E-02	0.5371E-02	0.0000E+00	0.0000E+00	0.8684E-03	0.6042E-03	0.1685E-03	0.5293E-03	0.8717E-03
Br	20	0.3842E-02	0.1893E-01	0.1215E-02	0.3364E-02	0.6183E-03	0.1963E-02	0.3596E-03	0.2729E-02	0.8282E-03
Zr	21	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Pb	22	0.0000E+00	0.0000E+00	0.0000E+00	0.6240E+00	0.1200E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Hg	23	0.4865E-02	0.0000E+00	0.2503E-02	0.5178E-02	0.3482E-02	0.0000E+00	0.1793E-02	0.1977E-01	0.5421E-02
Cd	24	0.8252E-01	0.1277E-02	0.4230E-02	0.4967E-01	0.7550E-02	0.1641E-01	0.3494E-02	0.1059E-01	0.3097E-01
Sb	25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.7254E-02	0.9821E-04	0.2129E-02	0.3135E-03	0.1228E-02
Ba	26	0.0000E+00	0.0000E+00	0.0000E+00	0.8069E-03	0.0000E+00	0.1624E+01	0.2001E+00	0.2226E+00	0.0000E+00
I	27	0.7939E-02	0.4790E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Mg	28	0.6064E-01	0.1280E+00	0.0000E+00	0.1561E+00	0.2739E-01	0.5395E-01	0.4623E-01	0.1734E+00	0.9370E-01
Na	29	0.4794E+00	0.4177E+00	0.3733E-01	0.1881E+00	0.2361E-01	0.6096E-01	0.0000E+00	0.1150E+00	0.0000E+00
Sm	30	0.5223E-04	0.7792E-04	0.0000E+00	0.0000E+00	0.3909E-04	0.5820E-04	0.4460E-04	0.8568E-04	0.2201E-03
Ce	31	0.1237E-02	0.1289E-02	0.1148E-03	0.3078E+00	0.3167E-03	0.9501E-01	0.6589E-03	0.8411E-01	0.1210E-02
U	32	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.7251E-04	0.1822E-03
Th	33	0.6197E-04	0.1369E-03	0.1914E-04	0.3860E-03	0.1328E-03	0.7700E-04	0.6129E-04	0.9427E-04	0.1691E-03
La	34	0.3290E-03	0.6961E-03	0.0000E+00	0.1490E-02	0.0000E+00	0.1626E-03	0.0000E+00	0.2983E-03	0.2152E-03
Au	35	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2143E-03	0.0000E+00	0.2060E-03	0.0000E+00	0.3593E-03
Ag	36	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3123E-03
Sc	37	0.5254E-04	0.8919E-04	0.1282E-04	0.2292E-03	0.2836E-04	0.8750E-04	0.6697E-04	0.6311E-04	0.2139E-03
Eu	38	0.0000F+00	0.4328E-05	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1025E-04	0.9554E-05	0.2220E-04
Cs	39	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3490E-03	0.0000E+00	0.1820E-03	0.0000E+00	0.1129E-03
NA	40	0.7400E-02	0.4400E-02	0.2510E-02	0.2030E-02	0.4370E-02	0.4750E-02	0.4230E-02	0.6430E-02	0.1080E-01
N3	41	0.5600E-02	0.6850E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2270E-02	0.1790E-02
N4	42	0.3020E+00	0.3340E+00	0.1380E+00	0.6590E+00	0.2930E+00	0.0000E+00	0.2070E+00	0.0000E+00	0.2570E+00
S2	43	0.0000E+00	0.2410E-01	0.0000E+00	0.0000E+00	0.4815E+00	0.0000E+00	0.4641E-02	0.1530E+00	0.1250E-01
S4	44	0.2826E-01	0.3057E-01	0.1369E-01	0.2046E-01	0.1986E-01	0.7501E-02	0.9762E-02	0.1044E-01	0.1565E-01
NO	45	0.0000E+00	0.3340E-01	0.0000E+00	0.0000E+00	0.1190E-01	0.0000E+00	0.1031E-01	0.0000E+00	0.2200E-02
NX	46	0.0000E+00	0.6320E-02	0.0000E+00	0.0000E+00	0.8847E-01	0.5370E-02	0.1869E-01	0.0000E+00	0.2380E-01

(continued)

TABLE 22 (continued)

		10	11	12	13	14	15	16	17	18
		36015	36016	36017	36018	36019	36021	36022	36025	36026
AL	1	0.2342E+01	0.6557E+00	0.5796E+00	0.1578E+01	0.2253E+01	0.4999E+00	0.1489E+01	0.8809E+00	0.2804E+01
Si	2	0.4422E+01	0.1894E+01	0.1748E+01	0.2814E+01	0.3364E+01	0.1309E+01	0.3358E+01	0.2516E+01	0.8481E+01
P	3	0.1785E-01	0.2585E+00	0.9752E-01	0.1038E+00	0.0000E+00	0.0000E+00	0.9898E-01	0.4019E+00	0.9229E-01
S	4	0.8591E+00	0.1119E+01	0.8519E+00	0.1038E+01	0.2099E+01	0.8845E+00	0.1149E+01	0.2556E+01	0.3002E+01
Cl	5	0.3580E-01	0.5613E-01	0.3795E-01	0.1139E+00	0.8533E+00	0.2413E-01	0.9453E-01	0.1735E+01	0.1171E+01
K	6	0.1200E+00	0.8914E-01	0.1141E+00	0.1574E+00	0.2422E+00	0.8616E-01	0.2121E+00	0.6754E+00	0.3467E+00
Ca	7	0.2249E+00	0.2563E+00	0.1684E+00	0.2137E+00	0.4126E+00	0.1287E+00	0.6646E+00	0.1755E+01	0.4424E+00
Ti	8	0.1365E+00	0.0000E+00	0.5520E-02	0.5276E-01	0.0000E+00	0.0000E+00	0.5921E-01	0.0000E+00	0.2170E+00
V	9	0.2959E-02	0.1404E-02	0.3028E-02	0.4431E-02	0.0000E+00	0.1864E-02	0.2934E-02	0.3153E-02	0.7998E-02
Cr	10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2449E-03	0.3422E-03
Mn	11	0.3354E-02	0.3301E-02	0.1435E-01	0.1845E-01	0.6562E-01	0.5737E-02	0.7625E-02	0.9250E-01	0.9293E-01
Fe	12	0.1630E+01	0.5014E+00	0.5143E+00	0.7475E+00	0.1265E+01	0.2530E+00	0.1343E+01	0.5701E+00	0.2228E+01
Co	13	0.1115E-03	0.0000E+00	0.7646E-04	0.2725E-03	0.0000E+00	0.1738E-04	0.1519E-03	0.8896E-04	0.4203E-03
Ni	14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Cu	15	0.9602E-01	0.1694E+00	0.2116E+00	0.1539E+00	0.0000E+00	0.1200E+00	0.1821E+00	0.8078E-01	0.4989E-01
Zn	16	0.3593E-01	0.1156E-01	0.2366E-01	0.3234E-01	0.0000E+00	0.4452E-01	0.1052E+00	0.6330E-01	0.0000E+00
Ga	17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
As	18	0.1900E-02	0.0000E+00	0.0000E+00	0.4394E-02	0.1810E-01	0.0000E+00	0.3144E-02	0.0000E+00	0.4799E-01
Se	19	0.8307E-03	0.1123E-02	0.1018E-02	0.1809E-02	0.4203E-02	0.8831E-03	0.0000E+00	0.9459E-03	0.4199E-02
Br	20	0.6213E-02	0.7779E-02	0.2239E-02	0.7274E-02	0.1279E-01	0.8703E-02	0.5256E-02	0.2058E-02	0.3483E-01
Zr	21	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4074E-01
Pb	22	0.3021E+00	0.0000E+00	0.2046E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1297E+00
Hg	23	0.1549E-02	0.4111E-02	0.2869E-02	0.0000E+00	0.6815E-03	0.2355E-03	0.3640E-02	0.4390E-02	0.1285E-02
Cd	24	0.1161E-01	0.5454E-02	0.1400E+00	0.4080E-02	0.1141E+00	0.3376E-01	0.2582E-01	0.5442E-01	0.5332E-01
Sb	25	0.0000E+00	0.2102E-02	0.1317E-02	0.1044E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.8920E-03	0.0000E+00
Ba	26	0.2451E+00	0.5505E+00	0.2153E+00	0.2005E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2761E+00	0.2503E+00
I	27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Mg	28	0.2752E+00	0.0000E+00	0.9298E-01	0.1431E+00	0.0000E+00	0.8364E-01	0.1779E+00	0.4204E+00	0.2624E+00
Na	29	0.1220E+00	0.1975E+00	0.3208E-01	0.1232E+00	0.7703E+00	0.5067E+00	0.1635E+00	0.9509E-02	0.1803E+01
Sm	30	0.1914E-03	0.3774E-03	0.1545E-03	0.1463E-03	0.1643E-03	0.3750E-04	0.1914E-03	0.4076E-03	0.7152E-03
Ce	31	0.4001E+00	0.9425E-03	0.8441E-03	0.1614E+00	0.2230E-02	0.4298E-01	0.1759E+00	0.2090E-02	0.6132E-02
U	32	0.1252E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.3431E-03	0.0000E+00	0.9222E-04	0.2452E-03	0.4999E-03
Th	33	0.8421E-03	0.3609E-03	0.1560E-03	0.2954E-03	0.2573E-03	0.7850E-04	0.2683E-03	0.1285E-03	0.8498E-03
La	34	0.1780E-02	0.4295E-03	0.4907E-03	0.9080E-03	0.0000E+00	0.0000E+00	0.9771E-03	0.1165E-02	0.5338E-02
Au	35	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3881E-06	0.2617E-03	0.0000E+00
Ag	36	0.0000E+00	0.1003E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2102E-03	0.0000E+00
Sc	37	0.3612E-03	0.7502E-04	0.1455E-03	0.1931E-03	0.3780E-03	0.8578E-04	0.1996E-03	0.1560E-03	0.5238E-03
Eu	38	0.3799E-04	0.6775E-05	0.1287E-04	0.1322E-04	0.0000E+00	0.0000E+00	0.1989E-04	0.1829E-03	0.0000E+00
Cs	39	0.0000E+00	0.5537E-04	0.1023E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1020E-03	0.0000E+00
NA	40	0.1751E-01	0.1598E-01	0.1175E-01	0.1474E-01	0.1449E-01	0.1374E-01	0.8770E-02	0.1640E-02	0.6270E-02
N3	41	0.1060E-02	0.0000E+00	0.7780E-02	0.2140E-02	0.0000E+00	0.1260E-02	0.2020E-02	0.6140E-02	0.4940E-02
Ms	42	0.5670E+00	0.5150E+00	0.3380E+00	0.3870E+00	0.3510E+00	0.3020E+00	0.1800E+00	0.4950E+00	0.1114E+01
S2	43	0.1262E-01	0.2675E-01	0.0000E+00	0.1924E+00	0.1755E+01	0.7303E-01	0.2246E+00	0.5640E-01	0.1447E+01
S4	44	0.1840E-01	0.1820E-01	0.1865E-01	0.2360E-01	0.3906E-01	0.2243E-01	0.2811E-01	0.5928E-01	0.7589E-01
NO	45	0.1060E-01	0.1590E-01	0.0000E+00	0.6494E-01	0.4406E+00	0.3570E-03	0.3700E-01	0.0000E+00	0.3628E+00
NX	46	0.4448E-01	0.6381E-01	0.0000E+00	0.1288E+00	0.5966E+00	0.4133E-01	0.7480E-01	0.0000E+00	0.6109E+00

(continued)

TABLE 22 (continued)

		19 36027	20 36028	21 36029	22 36030	23 36031	24 36032	25 36033	26 36034	27 36035
AL	1	0.4246E+00	0.4741E+00	0.7729E+00	0.3714E+00	0.4474E+00	0.3912E+00	0.1778E+00	0.1160E+01	0.5024E+00
Si	2	0.8792E+00	0.1415E+01	0.1422E+01	0.1097E+01	0.1072E+01	0.1072E+01	0.6336E+00	0.2943E+01	0.8936E+00
P	3	0.0000E+00	0.1363E+00	0.0000E+00	0.0000E+00	0.1905E-01	0.0000E+00	0.3046E-01	0.0000E+00	0.9554E-01
S	4	0.2078E+01	0.1312E+01	0.1892E+01	0.2195E+01	0.1848E+01	0.1048E+01	0.9138E+00	0.1890E+01	0.1794E+01
Cl	5	0.4814E+00	0.7433E-01	0.3829E-01	0.8796E-01	0.1663E-01	0.2048E-01	0.6381E-02	0.4994E+00	0.3756E+00
K	6	0.1403E+00	0.5530E-01	0.1061E+00	0.1207E+00	0.8496E-01	0.6846E-01	0.7554E-01	0.1041E+00	0.1127E+00
Ca	7	0.2238E+00	0.1145E+00	0.1389E+00	0.1415E+00	0.1072E+00	0.1336E+00	0.7383E-01	0.1336E+00	0.1306E+00
Ti	8	0.0000E+00	0.0000E+00	0.9845E-02	0.0000E+00	0.2625E-01	0.0000E+00	0.1809E-01	0.1471E-01	0.8248E-02
V	9	0.2916E-02	0.2642E-02	0.1909E-02	0.1422E-02	0.1360E-02	0.2614E-02	0.2504E-02	0.6578E-02	0.6578E-02
Cr	10	0.0000E+00	0.0000E+00	0.0000E+00	0.1219E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.6999E-02	0.0000E+00
Mn	11	0.5778E-02	0.9342E-02	0.8908E-02	0.8198E-02	0.1001E-01	0.5866E-02	0.2598E-02	0.1173E-01	0.8024E-02
Fe	12	0.4130E+00	0.3447E+00	0.5174E+00	0.3873E+00	0.1815E+00	0.1938E+00	0.1506E+00	0.6067E+00	0.3011E+00
Co	13	0.1292E-03	0.0000E+00	0.2342E-03	0.2691E-03	0.0000E+00	0.4627E-03	0.4137E-04	0.4361E-03	0.5704E-04
Ni	14	0.0000E+00	0.0000E+00	0.6497E-03	0.0000E+00	0.0000E+00	0.3903E-01	0.0000E+00	0.0000E+00	0.0000E+00
Cu	15	0.9325E-01	0.2045E+00	0.1116E+00	0.4334E+00	0.6929E-01	0.4537E-01	0.4703E+00	0.1245E+00	0.5753E+00
Zn	16	0.1345E-01	0.5419E-01	0.2956E-01	0.7471E-01	0.1616E-01	0.1903E-01	0.1114E-01	0.1095E+00	0.0000E+00
Ga	17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.8715E-01	0.0000E+00
As	18	0.7723E-03	0.0000E+00	0.2442E-02	0.5199E-02	0.1152E-02	0.0000E+00	0.0000E+00	0.1470E-01	0.0000E+00
Se	19	0.1284E-02	0.1957E-02	0.2823E-02	0.9546E-03	0.6159E-03	0.1497E-02	0.9919E-03	0.4922E-02	0.6265E-03
Br	20	0.1195E-02	0.2486E-03	0.1089E-02	0.1234E-02	0.7402E-02	0.4707E-02	0.1416E-02	0.1006E-01	0.8953E-02
Zr	21	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Pb	22	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.9502E-01	0.0000E+00	0.7388E-01	0.0000E+00	0.0000E+00
Hg	23	0.1289E-02	0.3285E-02	0.4833E-02	0.5451E-02	0.0000E+00	0.2953E-03	0.1013E-02	0.2189E-01	0.6774E-02
Cd	24	0.1907E-01	0.3518E-02	0.2803E-01	0.7636E-02	0.5743E-02	0.1758E-01	0.4194E-02	0.4446E-01	0.1413E+00
Sb	25	0.8253E-03	0.1835E-03	0.1094E-02	0.1036E-02	0.0000E+00	0.5515E-02	0.1648E-02	0.0000E+00	0.7361E-04
Ba	26	0.0000E+00	0.3138E+00	0.0000E+00	0.0000E+00	0.5741E-02	0.0000E+00	0.6604E-01	0.3486E+00	0.0000E+00
I	27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Mg	28	0.1236E+00	0.6347E-01	0.8225E-01	0.7099E-01	0.8117E-01	0.4786E-01	0.1811E-01	0.8980E-01	0.1465E+00
Na	29	0.0000E+00	0.0000E+00	0.4651E-01	0.6449E-01	0.8424E-01	0.4328E-01	0.4474E-01	0.8859E+00	0.6290E+00
Sm	30	0.1089E-04	0.4596E-04	0.1590E-03	0.5916E-04	0.6266E-04	0.1412E-03	0.4107E-04	0.2250E-03	0.6154E-04
Ce	31	0.0000E+00	0.9005E-03	0.9244E-03	0.8733E-03	0.8510E-01	0.6257E-03	0.2791E-03	0.7535E+00	0.8457E-03
U	32	0.0000E+00	0.1801E-03	0.1909E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.4625E-04	0.3176E-03	0.0000E+00
Th	33	0.1182E-03	0.1321E-03	0.2110E-03	0.3859E-03	0.7998E-04	0.8712E-04	0.3827E-04	0.1021E-02	0.7831E-04
La	34	0.0000E+00	0.0000E+00	0.2237E-03	0.9721E-04	0.2033E-03	0.3195E-04	0.7309E-04	0.1210E-02	0.1030E-03
Au	35	0.1091E-03	0.2400E-04	0.8992E-04	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Ag	36	0.9456E-04	0.1561E-03	0.0000E+00	0.8124E-04	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Sc	37	0.7663E-04	0.1655E-03	0.1182E-03	0.3125E-03	0.5464E-04	0.1095E-03	0.3392E-04	0.5769E-03	0.7052E-04
Eu	38	0.1047E-04	0.0000E+00	0.3531E-05	0.0000E+00	0.1108E-04	0.3006E-05	0.1738E-05	0.2201E-03	0.0000E+00
Cs	39	[illegible]	0.2675E-03	0.1111E-03	0.2047E-03	0.0000E+00	0.4091E-03	0.0000E+00	0.0000E+00	0.0000E+00
NA	40	0.2840E-02	0.7720E-02	0.5080E-02	0.6500E-02	0.8460E-02	0.7550E-02	0.5320E-02	0.7360E-02	0.6140E-02
N3	41	0.1570E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.8300E-03	0.7160E-02	0.1530E-02	0.3710E-02	0.6380E-02
N5	42	0.5320E+00	0.4140E+00	0.2800E+00	0.3610E+00	0.2150E+00	0.2070E+00	0.1610E+00	0.4790E+00	0.2370E+00
S2	43	0.2387E+00	0.3931E+00	0.1168E+00	0.4970E+00	0.0000E+00	0.5914E-01	0.0000E+00	0.1130E+01	0.3200E-02
S4	44	0.4270E-01	0.2920E-01	0.4457E-01	0.5016E-01	0.4643E-01	0.2348E-01	0.2182E-01	0.4461E-01	0.4485E-01
NO	45	0.3908E-01	0.6069E-01	0.5003E-01	0.0000E+00	0.0000E+00	0.3805E-01	0.0000E+00	0.5126E-01	0.0000E+00
NX	46	0.1086E+00	0.1202E+00	0.8104E-01	0.0000E+00	0.0000E+00	0.7190E-01	0.0000E+00	0.1736E+00	0.0000E+00

(continued)

TABLE 22 (continued)

		28 36036
AL	1	0.1025E+01
Si	2	0.1804E+01
P	3	0.0000E+00
S	4	0.3256E+01
Cl	5	0.5329E+00
K	6	0.1728E+00
Ca	7	0.7480E+00
Ti	8	0.2088E-01
V	9	0.9496E-02
Cr	10	0.0000E+00
Mn	11	0.8356E-02
Fe	12	0.9872E+00
Co	13	0.3035E-03
Ni	14	0.0000E+00
Cu	15	0.1414E+00
Zn	16	0.3959E-01
Ga	17	0.0000E+00
As	18	0.2126E-01
Se	19	0.4805E-02
Br	20	0.9965E-02
Zr	21	0.0000E+00
Pb	22	0.0000E+00
Hg	23	0.2181E-02
Cd	24	0.9171E-02
Sb	25	0.1215E-03
Ba	26	0.0000E+00
I	27	0.0000E+00
Mg	28	0.1964E+00
Na	29	0.1240E+01
Sm	30	0.2014E-03
Ce	31	0.1805E+00
U	32	0.1380E-03
Th	33	0.2435E-03
La	34	0.5944E-03
Au	35	0.0000E+00
Ag	36	0.0000E+00
Sc	37	0.2733E-03
Eu	38	0.1058E-04
Cs	39	0.0000E+00
NA	40	0.9200E-02
N3	41	0.6800E-02
Ms	42	0.4230E+00
S2	43	0.1442E+01
S4	44	0.7665E-01
NO	45	0.5098E+00
NX	46	0.7761E+00

TABLE 23. ESTIMATED UNCERTAINTIES IN CONCENTRATIONS OF ELEMENTS DETERMINED FROM THE AMBIENT HI-VOL FILTERS

ERROR MATRIX

		1	2	3	4	5	6	7	8	9
		36005	36007	36008	36009	36010	36011	36012	36013	36014
AL	1	0.4794E-02	0.3934E-01	0.4149E-02	0.1269E-01	0.4756E-02	0.4114E-02	0.3499E-02	0.1222E-01	0.7979E-02
Si	2	0.6474E-01	0.1200E+00	0.1172E+00	0.5214E+00	0.2318E+00	0.1348E+00	0.1788E+00	0.1744E+00	0.1348E+00
P	3	0.3764E-02	0.4751E-02	0.5357E-01	0.1936E-01	0.1060E+00	0.6162E-01	0.8174E-01	0.7973E-01	0.6162E-01
S	4	0.5270E-01	0.5107E-01	0.3014E-01	0.1341E+00	0.5961E-01	0.3466E-01	0.4598E-01	0.4485E-01	0.3466E-01
Cl	5	0.1137E-01	0.7851E-02	0.7919E-02	0.1465E-01	0.5729E-02	0.3832E-02	0.6499E-02	0.1061E-01	0.5803E-02
K	6	0.9034E-02	0.1069E-01	0.6697E-02	0.2979E-01	0.1325E-01	0.7702E-02	0.1022E-01	0.9967E-02	0.7702E-02
Ca	7	0.1656E-01	0.2257E-01	0.6697E-02	0.2979E-01	0.1325E-01	0.7702E-02	0.1022E-01	0.9967E-02	0.7702E-02
Ti	8	0.1054E-01	0.1782E-01	0.3348E-02	0.1361E-01	0.6624E-02	0.3851E-02	0.5109E-02	0.4983E-02	0.3851E-02
V	9	0.9542E-04	0.1026E-03	0.1034E-03	0.2702E-03	0.7152E-04	0.7700E-04	0.1226E-03	0.6381E-04	0.2342E-03
Cr	10	0.2032E-03	0.3377E-03	0.1868E-03	0.7947E-03	0.4623E-03	0.2516E-03	0.3016E-03	0.2620E-03	0.2264E-03
Mn	11	0.8904E-04	0.1194E-03	0.4071E-04	0.2789E-03	0.1793E-03	0.1460E-03	0.1063E-03	0.1199E-03	0.1007E-03
Fe	12	0.4216E-01	0.6770E-01	0.4967E-01	0.2210E+00	0.9825E-01	0.5713E-01	0.7578E-01	0.7392E-01	0.5713E-01
Co	13	0.1153E-04	0.2007E-04	0.4419E-05	0.6808E-04	0.3724E-05	0.3732E-05	0.3012E-05	0.2281E-05	0.2040E-05
Ni	14	0.4445E-02	0.7013E-02	0.3295E-02	0.1466E-01	0.1146E-01	0.3790E-02	0.5382E-02	0.4904E-02	0.3790E-02
Cu	15	0.5721E-01	0.8195E-01	0.2511E-01	0.1117E+00	0.4968E-01	0.2888E-01	0.3832E-01	0.3738E-01	0.2888E-01
Zn	16	0.1999E-02	0.1728E-02	0.4211E-03	0.9692E-02	0.2065E-02	0.3463E-02	0.2225E-02	0.3587E-02	0.2226E-02
Ga	17	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39
As	18	0.2630E-03	0.2630E-03	0.2630E-03	0.3114E-03	0.1349E-03	0.5331E-04	0.2630E-03	0.1244E-03	0.2630E-03
Se	19	0.5771E-04	0.1611E-03	0.6053E-04	0.6053E-04	0.4342E-04	0.3021E-04	0.8428E-05	0.2647E-04	0.4359E-04
Br	20	0.4123E-04	0.1923E-03	0.6649E-04	0.1949E-03	0.4420E-04	0.2272E-04	0.5346E-04	0.3114E-04	0.4834E-04
Zr	21	0.4746E-01	0.4746E-01	0.2344E-01	0.1043E+00	0.4637E-01	0.2696E-01	0.3576E-01	0.3488E-01	0.2696E-01
Pb	22	0.2794E+00	0.2794E+00	0.8203E-01	0.1435E+01	0.6381E+00	0.9435E-01	0.1252E+00	0.1221E+00	0.9435E-01
Hg	23	0.2788E-03	0.8071E-04	0.1519E-03	0.3838E-03	0.2281E-03	0.2586E-04	0.1325E-03	0.2079E-03	0.3010E-03
Cd	24	0.4126E-02	0.2555E-03	0.4230E-03	0.2483E-02	0.7550E-03	0.8203E-03	0.5240E-03	0.1059E-02	0.3097E-02
Sb	25	0.1732E-04	0.2074E-04	0.5694E-05	0.1399E-03	0.8813E-04	0.4869E-04	0.3385E-04	0.7225E-04	0.2189E-04
Ba	26	0.1842E+00	0.1842E+00	0.1016E+00	0.3352E-01	0.2009F+00	0.1168E+00	0.1550E+00	0.1512E+00	0.1168E+00
I	27	0.7939E-03	0.4790E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03
Mg	28	0.9770E-02	0.2025E-01	0.6291E-03	0.2567E-01	0.5193E-02	0.8666E-02	0.7714E-02	0.1783E-01	0.9759E-02
Na	29	0.4996E-02	0.4498E-02	0.5321E-03	0.2593E-02	0.5690E-03	0.7895E-03	0.2193E-03	0.1379E-02	0.1507E-03
Sm	30	0.8017E-05	0.1198E-04	0.8987E-07	0.3998E-06	0.4091E-05	0.2963E-05	0.2303E-05	0.4353E-05	0.2214E-05
Ce	31	0.1237E-03	0.1289E-03	0.1723E-04	0.1539E-01	0.3167E-04	0.9501E-02	0.9893E-04	0.8411E-02	0.1210E-03
U	32	0.2098E-04	0.2098E-04	0.2098E-04	0.2098E-04	0.2098E-04	0.2098E-04	0.2098E-04	0.7251E-05	0.1821E-04
Th	33	0.6107E-05	0.6843E-05	0.1914E-05	0.5790E-04	0.1328E-04	0.1155E-04	0.6129E-05	0.1414E-04	0.1691E-04
La	34	0.2009E-04	0.3660E-04	0.8067E-05	0.7750E-04	0.1834E-04	0.1398E-04	0.1365E-04	0.2041E-04	0.1537E-04
Au	35	0.7540E-06	0.1190E-05	0.5590E-06	0.2487E-05	0.2690E-05	0.6429E-06	0.2452E-05	0.8319E-06	0.3828E-05
Ag	36	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.3123E-04
Sc	37	0.3113E-05	0.5220E-05	0.1056E-05	0.1302E-04	0.2227E-05	0.4766E-05	0.3891E-05	0.3686E-05	0.1107E-04
Eu	38	0.4485E-06	0.1342E-05	0.3325E-06	0.1479E-05	0.6577E-06	0.3824E-06	0.1614E-05	0.1532E-05	0.3922E-05
Cs	39	0.7169E-05	0.1328E-04	0.3198E-05	0.1423E-04	0.4945E-04	0.3679E-05	0.1535E-04	0.4760E-05	0.1986E-04
NA	40	0.1480E-02	0.8800E-03	0.5020E-03	0.4060E-03	0.8740E-03	0.9500E-03	0.8460E-03	0.1286E-02	0.2160E-02
N3	41	0.1120E-02	0.1370E-02	0.7759E-03	0.7759E-03	0.7759E-03	0.7759E-03	0.7759E-03	0.4540E-03	0.3580E-03
Ms	42	0.4530E-01	0.5010E-01	0.2070E-01	0.9885E-01	0.4395E-01	0.5624E-01	0.3105E-01	0.5624E-01	0.3855E-01
S2	43	0.8331E-01	0.4820E-02	0.8331E-01	0.8331E-01	0.9631E-01	0.8331E-01	0.9282E-03	0.3060E-01	0.8331E-01
S4	44	0.4239E-02	0.4586E-02	0.2053E-02	0.3069E-02	0.2978E-02	0.1125E-02	0.1464E-02	0.1566E-02	0.2348E-02
NO	45	0.2124E-01	0.6680E-02	0.2124E-01	0.2124E-01	0.1615E-02	0.2124E-01	0.2063E-02	0.2124E-01	0.2124E-01
NX	46	0.3542E-01	0.1264E-02	0.3542E-01	0.3542E-01	0.1769E-01	0.1074E-02	0.3738E-02	0.3542E-01	0.3542E-01

(continued)

TABLE 23 (continued)

		10 36015	11 36016	12 36017	13 36018	14 36019	15 36021	16 36022	17 36025	18 36026
AL	1	0.2424E-01	0.8055E-02	0.3222E-02	0.1635E-01	0.2550E-01	0.5723E-02	0.1546E-01	0.4627E-02	0.2883E-02
Si	2	0.2653E+00	0.4680E+00	0.1932E+00	0.1847E+00	0.9418E+00	0.2290E+00	0.1856E+00	0.1390E+00	0.1746E+00
P	3	0.9918E-02	0.2139E+00	0.8832E-01	0.8442E-01	0.4306E+00	0.1047E+00	0.8484E-01	0.6357E-01	0.7982E-01
S	4	0.6822E-01	0.1203E+00	0.4968E-01	0.4749E-01	0.2422E+00	0.5889E-01	0.4772E-01	0.3576E-01	0.4490E-01
Cl	5	0.6373E-02	0.2012E-01	0.5181E-02	0.8658E-02	0.5751E-01	0.5199E-02	0.7732E-02	0.1782E-01	0.1236E-01
K	6	0.1516E-01	0.2674E-01	0.1104E-01	0.1055E-01	0.5382E-01	0.1309E-01	0.1060E-01	0.7946E-02	0.9978E-02
Ca	7	0.1516E-01	0.2674E-01	0.1104E-01	0.1055E-01	0.5382E-01	0.1309E-01	0.1060E-01	0.7946E-02	0.9978E-02
Ti	8	0.7580E-02	0.1337E-01	0.5520E-02	0.5276E-02	0.2691E-01	0.6544E-02	0.5302E-02	0.3973E-02	0.4989E-02
V	9	0.2959E-03	0.7018E-04	0.3028E-04	0.4431E-03	0.1757E-03	0.1864E-03	0.2934E-03	0.3153E-04	0.3999E-03
Cr	10	0.5022E-03	0.6486E-03	0.4066E-03	0.2919E-03	0.1888E-02	0.3490E-03	0.3571E-03	0.3265E-03	0.4129E-03
Mn	11	0.1548E-03	0.1741E-03	0.1619E-03	0.1997E-03	0.2103E-02	0.2115E-03	0.1004E-03	0.1019E-03	0.9379E-03
Fe	12	0.1124E+00	0.1983E+00	0.8188E-01	0.7827E-01	0.3992E+00	0.9706E-01	0.7865E-01	0.5893E-01	0.7400E-01
Co	13	0.4670E-05	0.4738E-05	0.3360E-05	0.5048E-05	0.3941E-04	0.3361E-05	0.3931E-05	0.2720E-05	0.6340E-05
Ni	14	0.7460E-02	0.1316E-01	0.7134E-02	0.5193E-02	0.2648E-01	0.6898E-02	0.5218E-02	0.3910E-02	0.4910E-02
Cu	15	0.5685E-01	0.1003E+00	0.4140E-01	0.3957E-01	0.2018E+00	0.4908E-01	0.3977E-01	0.2980E-01	0.3742E-01
Zn	16	0.2415E-02	0.3136E-02	0.1645E-02	0.3879E-02	0.3385E-02	0.5246E-02	0.5598E-02	0.3423E-02	0.6275E-03
Ga	17	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39
As	18	0.9502E-04	0.2630E-03	0.2630E-03	0.2197E-03	0.9048E-03	0.2630E-03	0.1572E-03	0.2630E-03	0.4799E-03
Se	19	0.4153E-04	0.5615E-04	0.1018E-04	0.9047E-04	0.2101E-03	0.4416E-04	0.6053E-04	0.2838E-04	0.4199E-04
Br	20	0.6692E-04	0.4113E-03	0.1213E-03	0.7543E-04	0.6848E-03	0.9041E-04	0.5565E-04	0.1096E-03	0.3501E-03
Zr	21	0.5306E-01	0.9360E-01	0.3864E-01	0.3694E-01	0.1884E+00	0.4580E-01	0.3712E-01	0.2781E-01	0.3492E-01
Pb	22	0.7299E+00	0.3276E+00	0.5315E+00	0.1293E+00	0.6593E+00	0.1603E+00	0.1299E+00	0.9734E-01	0.1222E+00
Hg	23	0.1436E-03	0.3187E-03	0.1885E-03	0.3543E-04	0.5051E-03	0.7504E-04	0.2246E-03	0.2507E-03	0.1070E-03
Cd	24	0.5803E-03	0.8181E-03	0.1400E-01	0.2040E-03	0.5704E-02	0.1688E-02	0.1291E-02	0.2721E-02	0.2666E-02
Sb	25	0.3316E-04	0.5567E-04	0.2716E-04	0.1166E-03	0.8166E-04	0.2905E-04	0.4528E-04	0.1902E-04	0.5477E-04
Ba	26	0.2299E+00	0.4056E+00	0.1674E+00	0.1600E+00	0.8163E+00	0.1985E+00	0.1608E+00	0.1205E+00	0.1513E+00
I	27	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03
Mg	28	0.2827E-01	0.2512E-02	0.9871E-02	0.2223E-01	0.5056E-02	0.1352E-01	0.1831E-01	0.6362E-01	0.2673E-01
Na	29	0.1574E-02	0.2601E-02	0.5914E-02	0.1475E-02	0.8935E-02	0.2686E-02	0.1877E-02	0.2985E-03	0.9128E-02
Sm	30	0.9675E-05	0.1905E-04	0.7800E-05	0.7387E-05	0.8607E-05	0.1970E-05	0.9642E-05	0.2044E-04	0.3583E-04
Ce	31	0.2001E-01	0.9424E-04	0.8440E-04	0.1614E-01	0.3345E-03	0.6447E-02	0.8794E-02	0.2090E-03	0.3066E-03
U	32	0.2098E-04	0.2098E-04	0.2098E-04	0.2098E-04	0.3431E-04	0.2098E-04	0.9222E-05	0.2452E-04	0.4999E-04
Th	33	0.8421E-04	0.3609E-04	0.1560E-04	0.4431E-04	0.2573E-04	0.1570E-04	0.2683E-04	0.1284E-04	0.8498E-04
La	34	0.2644E-04	0.6772E-04	0.4294E-04	0.3834E-04	0.8791E-04	0.1195E-04	0.1627E-04	0.1588E-04	0.5722E-04
Au	35	0.1265E-05	0.2232E-05	0.9215E-06	0.8808E-06	0.4492E-05	0.1092E-05	0.2666E-05	0.2880E-05	0.8328E-06
Ag	36	0.1207E-04	0.1003E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1051E-04	0.1207E-04
Sc	37	0.1880E-04	0.5322E-05	0.1725E-05	0.1018E-04	0.2174E-04	0.4984E-05	0.1050E-04	0.1719E-05	0.2667E-04
Eu	38	0.4614E-05	0.1664E-05	0.1915E-05	0.1919E-05	0.2672E-05	0.6497E-06	0.2569E-05	0.1910E-05	0.4954E-06
Cs	39	0.7241E-05	0.2130E-04	0.1221E-04	0.5040E-05	0.2571E-04	0.6250E-05	0.5065E-05	0.6769E-05	0.4765E-05
NA	40	0.3502E-02	0.3196E-02	0.2350E-02	0.2948E-02	0.2898E-02	0.2748E-02	0.1754E-02	0.3280E-03	0.1254E-02
N3	41	0.2120E-03	0.7759E-03	0.1556E-02	0.4280E-03	0.7759E-03	0.2520E-03	0.4040E-03	0.1228E-02	0.9880E-03
Ms	42	0.8505E-01	0.7725E-01	0.5070E-01	0.5805E-01	0.5265E-01	0.4530E-01	0.2700E-01	0.7425E-01	0.1671E+00
S2	43	0.2523E-02	0.5350E-02	0.8331E-01	0.3849E-01	0.3510E+00	0.1461E-01	0.4492E-01	0.1128E-01	0.2894E+00
S4	44	0.2760E-02	0.2731E-02	0.2797E-02	0.3541E-02	0.5859E-02	0.3365E-02	0.4217E-02	0.8893E-02	0.1138E-01
NO	45	0.2120E-02	0.3180E-02	0.2124E-01	0.1299E-01	0.8812E-01	0.7140E-04	0.5800E-03	0.2124E-01	0.7256E-01
NX	46	0.8896E-02	0.1276E-01	0.3542E-01	0.2575E-01	0.1193E+00	0.8266E-02	0.1496E-01	0.3542E-01	0.1222E+00

(continued)

TABLE 23 (continued)

		19	20	21	22	23	24	25	26	27
		36027	36028	36029	36030	36031	36032	36033	36034	36035
AL	1	0.4834E-02	0.2846E-02	0.4246E-02	0.4448E-02	0.5018E-02	0.2254E-02	0.2238E-03	0.1234E-01	0.5475E-02
Si	2	0.1865E+00	0.2701E+00	0.2297E+00	0.2304E+00	0.1732E+00	0.1732E+00	0.5117E-01	0.2377E+00	0.1444E+00
P	3	0.8526E-01	0.1235E+00	0.1050E+00	0.1053E+00	0.6475E-02	0.7918E-01	0.2339E-01	0.1087E+00	0.6599E-01
S	4	0.4796E-01	0.6945E-01	0.5907E-01	0.5925E-01	0.4454E-01	0.4454E-01	0.1316E-01	0.6112E-01	0.3712E-01
Cl	5	0.1091E-01	0.1571E-01	0.5848E-02	0.8186E-02	0.3860E-02	0.4031E-02	0.1206E-02	0.2861E-01	0.2098E-01
K	6	0.1066E-01	0.1543E-01	0.1313E-01	0.1317E-01	0.9898E-02	0.9898E-02	0.2924E-02	0.1358E-01	0.8248E-02
Ca	7	0.1066E-01	0.1543E-01	0.1313E-01	0.1317E-01	0.9898E-02	0.9898E-02	0.2924E-02	0.1358E-01	0.8248E-02
Ti	8	0.5329E-02	0.7716E-02	0.6563E-02	0.6583E-02	0.4520E-02	0.4949E-02	0.1335E-02	0.6791E-02	0.4124E-02
V	9	0.2916E-03	0.1321E-03	0.1909E-04	0.1422E-03	0.1360E-03	0.2614E-04	0.2504E-04	0.6578E-03	0.3289E-03
Cr	10	0.2880E-03	0.3763E-03	0.5044E-03	0.6108E-03	0.2588E-03	0.3705E-03	0.9629E-04	0.1166E-02	0.3080E-03
Mn	11	0.8581E-04	0.1318E-03	0.1199E-03	0.2826E-02	0.1189E-03	0.8356E-04	0.3194E-04	0.3876E-03	0.4328E-03
Fe	12	0.7904E-01	0.1145E+00	0.9736E-01	0.9766E-01	0.7341E-01	0.7341E-01	0.2169E-01	0.1007E+00	0.6117E-01
Co	13	0.3727E-05	0.3402E-05	0.5293E-05	0.5628E-05	0.1945E-05	0.6735E-05	0.1079E-05	0.7313E-05	0.2509E-05
Ni	14	0.5244E-02	0.7594E-02	0.9388E-02	0.7084E-02	0.4871E-02	0.1535E-01	0.2030E-02	0.6683E-02	0.4059E-02
Cu	15	0.3997E-01	0.5787E-01	0.4923E-01	0.4938E-01	0.3712E-01	0.3712E-01	0.1097E-01	0.5093E-01	0.3093E-01
Zn	16	0.2051E-02	0.3286E-02	0.2020E-02	0.4185E-02	0.2255E-02	0.1376E-02	0.6646E-03	0.1174E-01	0.5187E-03
Ga	17	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39	0.1701E+39
As	18	0.7723E-04	0.2630E-03	0.1221E-03	0.2600E-03	0.5759E-04	0.2630E-03	0.2630E-03	0.7349E-03	0.2630E-03
Se	19	0.6423E-04	0.9786E-04	0.2823E-04	0.4773E-04	0.3079E-04	0.1497E-04	0.9919E-05	0.2461E-03	0.3132E-04
Br	20	0.1849E-04	0.3055E-04	0.6661E-04	0.7374E-04	0.7647E-04	0.2434E-03	0.7320E-04	0.1040E-03	0.2727E-03
Zr	21	0.3730E-01	0.5401E-01	0.4594E-01	0.4609E-01	0.3464E-01	0.3464E-01	0.1023E-01	0.4754E-01	0.2887E-01
Pb	22	0.1305E+00	0.1891E+00	0.1608E+00	0.1613E+00	0.4765E+00	0.1213E+00	0.1408E+00	0.1664E+00	0.1010E+00
Hg	23	0.1104E-03	0.2281E-03	0.2942E-03	0.3249E-03	0.3323E-04	0.6160E-04	0.6241E-04	0.2336E-03	0.3707E-03
Cd	24	0.9535E-03	0.5277E-03	0.1402E-02	0.3818E-03	0.5743E-03	0.8791E-03	0.4194E-03	0.2223E-02	0.7063E-02
Sb	25	0.2207E-04	0.9689E-04	0.2790E-04	0.2742E-04	0.1939E-04	0.6679E-04	0.1992E-04	0.7568E-04	0.5057E-04
Ba	26	0.1616E+00	0.2341E+00	0.1991E+00	0.1997E+00	0.1114E-01	0.1501E+00	0.4435E-01	0.2060E+00	0.1251E+00
I	27	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03	0.6364E-03
Mg	28	0.2574E-01	0.1071E-01	0.8928E-02	0.1164E-01	0.8632E-02	0.7931E-02	0.1968E-02	0.1928E-01	0.1505E-01
Na	29	0.2421E-03	0.3044E-03	0.7835E-03	0.9591E-03	0.1073E-02	0.6703E-03	0.5142E-03	0.9162E-02	0.6474E-02
Sm	30	0.5518E-05	0.2410E-05	0.8040E-05	0.6095E-05	0.3202E-05	0.7129E-05	0.4165E-06	0.1134E-04	0.6266E-05
Ce	31	0.5221E-02	0.2251E-03	0.9244E-04	0.8733E-04	0.8510E-02	0.9385E-04	0.2791E-04	0.3768E-01	0.8457E-04
U	32	0.2098E-04	0.1801E-04	0.1909E-04	0.2098E-04	0.2098E-04	0.2098E-04	0.4625E-05	0.3176E-04	0.2098E-04
Th	33	0.1182E-04	0.1321E-04	0.2110E-04	0.3859E-04	0.7998E-05	0.8712E-05	0.3827E-05	0.1531E-03	0.7831E-05
La	34	0.1293E-04	0.1754E-04	0.3384E-04	0.2809E-04	0.1782E-04	0.1364E-04	0.5604E-05	0.5054E-04	0.1952E-04
Au	35	0.1608E-05	0.1421E-05	0.1629E-05	0.1099E-05	0.8262E-06	0.8262E-06	0.2441E-06	0.1134E-05	0.6885E-06
Ag	36	0.4728E-05	0.7805E-05	0.1207E-04	0.8124E-05	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04	0.1207E-04
Sc	37	0.4392E-05	0.9064E-05	0.1573E-05	0.1627E-04	0.5162E-05	0.1360E-05	0.4156E-06	0.2950E-04	0.7850E-05
Eu	38	0.1663E-05	0.9043E-06	0.1198E-05	0.6537E-06	0.2449E-05	0.4914E-06	0.5000E-06	0.2269E-04	0.4095E-06
Cs	39	0.1074E-04	0.4385E-04	0.1404E-04	0.3509E-04	0.4727E-05	0.1615E-04	0.3336E-05	0.6487E-05	0.3939E-05
NA	40	0.5680E-03	0.1544E-02	0.1016E-02	0.1300E-02	0.1692E-02	0.1510E-02	0.1064E-02	0.1472E-02	0.1228E-02
N3	41	0.3140E-03	0.7759E-03	0.7759E-03	0.7759E-03	0.1660E-03	0.1432E-02	0.3060E-03	0.7420E-03	0.1276E-02
MS	42	0.7980E-01	0.6210E-01	0.4200E-01	0.5415E-01	0.3225E-01	0.3105E-01	0.2415E-01	0.7185E-01	0.3555E-01
S2	43	0.4774E-01	0.7863E-01	0.2336E-01	0.9940E-01	0.8331E-01	0.1183E-01	0.8331E-01	0.2259E+00	0.6400E-03
S4	44	0.6404E-02	0.4381E-02	0.6685E-02	0.7524E-02	0.6965E-02	0.3522E-02	0.3273E-02	0.6692E-02	0.6727E-02
ND	45	0.7816E-02	0.1214E-01	0.1001E-01	0.2124E-01	0.2124E-01	0.7610E-02	0.2124E-01	0.1025E-01	0.2124E-01
NX	46	0.2171E-01	0.2404E-01	0.1621E-01	0.3542E-01	0.3542E-01	0.1438E-01	0.3542E-01	0.3473E-01	0.3542E-01

(continued)

TABLE 23 (continued)

		28 36036
AL	1	0.1087E-01
Si	2	0.1993E+00
P	3	0.9113E-01
S	4	0.5126E-01
Cl	5	0.2968E-01
K	6	0.1139E-01
Ca	7	0.1139E-01
Ti	8	0.5695E-02
V	9	0.9496E-04
Cr	10	0.3856E-03
Mn	11	0.1093E-03
Fe	12	0.8448E-01
Co	13	0.5538E-05
Ni	14	0.5605E-02
Cu	15	0.4272E-01
Zn	16	0.2406E-02
Ge	17	0.1701E+39
As	18	0.2126E-03
Se	19	0.4805E-04
Br	20	0.1023E-03
Zr	21	0.3987E-01
Pb	22	0.1395E+00
Hg	23	0.1565E-03
Cd	24	0.4585E-03
Sb	25	0.7083E-04
Ba	26	0.1728E+00
I	27	0.6364E-03
Mg	28	0.3028E-01
Na	29	0.1265E-01
Sm	30	0.2035E-05
Ce	31	0.9025E-02
U	32	0.1380E-04
Th	33	0.2435E-04
La	34	0.1408E-04
Au	35	0.9508E-06
Ag	36	0.1207E-04
Sc	37	0.1422E-04
Eu	38	0.1719E-05
Cs	39	0.5440E-05
NA	40	0.1840E-02
N3	41	0.1360E-02
Mo	42	0.6345E-01
S2	43	0.2885E+00
S4	44	0.1150E-01
NO	45	0.1019E+00
NX	46	0.1552E+00

TABLE 24. NAA ANALYSES OF SOIL SAMPLES

ELEMENT	MICROGRAMS OF ELEMENT/GRAM MATRIX			
	LOCATION			
	WAQ(16)	NAQ(13)	SAQ(15)	SITE 2
TI	1333	4918	8614	8792
I	<1	19.4	<1	5.35
MN	314	4546	3629	686
MG	1827	3533	6282	9416
CU	<50	585	58.8	270
V	11.1	77.6	51.1	96.2
CL	<150	<150	325	<150
AL	7582	53419	45180	71984
HG	<.01	<.01	<.01	<.01
SM	12.5	6.06	25.2	13.1
U	11.2	8.98	9.54	12.2
LA	120	79.5	199	122
CD	5.05	<2	<1	6.17
AU	<.0004	<.0004	<.0004	<.0004
AS	20.5	28.9	19.2	13
SB	1.67	3.92	1.4	1.35
BR	12.47	13.2	16.2	8.72
NA	1126	1046	758	736
K	<750	<750	<750	<750
CE	247	293	183	214
CA	10884	15381	19494	14007
SE	3.9	1.33	1.42	1.91
TH	22.1	21.3	19.7	27.9
CR	88.1	86.6	105	117
EU	4.86	8.35	5.15	5.63
YT	7.19	11.9	8.79	9.39
BA	170	216	203	129
CS	6.16	7.89	7.25	8.12
AG	<.001	<.001	<.001	<.001
NI	<10	<10	<10	<10
SC	12.5	16.3	10.6	17.3
RB	71.1	75	60.2	56.1
FE	25171	39455	31310	31661
ZN	<100	<100	<100	<100
CO	10.9	16.2	16.3	10.4

SECTION 9

SOURCE IMPACT ON TARGET AREA

Three approaches were taken to quantify the impact of the source (Scholz plant) on the study area. First, ISC Model[63] predictions were made for hourly average downwind concentrations at the locations of the ambient sampling stations. The model was used to predict only SO_2 and NO_x concentrations; $SO_4^=$ and TSP concentrations were predicted by scaling plant emission rates of these quantities to the predicted SO_2 and NO_x results. Second, factor analysis was applied to the correlation matrix[64] of an ambient data base comprised of SO_2, NO_x, TSP, SO_4, NO_3, wind direction relative to the source and sampler locations, and 23 elements for which reasonably good concentration values were available from the teflon membrane hi-vol filters. This analysis provided much insight into the probable number and nature of sources which had a detectable impact on the ambient stations, but did not quantify the impact on individual stations. Finally, Target Transformation Factor Analysis[65-68] was used in analyzing the data to isolate and quantify the impacts of specific sources having known signatures at each specific sampling location. The target transformation analysis used here involved a set of computer codes known collectively as "FANTASIA" (Factor Analysis To Apportion Sources In Aerosols.[68] FANTASIA was developed by P. Hopke and his co-workers at the University of Illinois-Urbana, and a copy of the code was very kindly provided to Southern Research by Dr. Hopke.

Because of surprisingly high background concentrations of nitrates and sulfates, dispersion modeling was not found to be particularly useful in sorting out the plant's contribution to their concentrations. At most distances dispersion model predictions of particulate and sulfate concentrations would have represented small increments to be superposed on the relatively high background concentrations - increments small enough to be almost list in the "noise". And because of a source strength of zero (undetectable) nitrates, dispersion modeling predicted zero nitrate contribution for the plant. Thus factor analysis became the primary tool used in quantifying the source contribution to ambient loadings. Two forms of factor analysis were used in interpreting the data. First, principal component factor analysis was performed on the correlation matrix of the data to aid in identifying potential sources other than the Scholz

Plant, and to screen the data for elements exhibiting "unique" behavior which might result from analytical errors or the inclusion of elements for which the concentrations were too close to detection limits to be reliable. The second, and more informative analysis, was performed using the technique known as Target Transformation Factor Analysis. The later technique permits testing of specific source vectors (source "fingerprints") as possible contributors to the samples, and once a suitable set of source vectors has been selected, the method provides a reconstruction of the original data from the source signatures, quantifying the contributions of each source.

CORRELATION MATRIX ANALYSIS

A form of principal component factor analysis was performed on the complete set of elemental analysis data (from which the data presented in Table 22 was excerpted) augmented by the concentrations found for nitrates, nitric acid, sulfates, SO_2, NO, NO_x, TSP, and a variable related to the relative direction of the wind with respect to the plant and the sampling location. Elements which showed low values of communality in these analyses were excluded from the data set to be used in the TTFA approach. The one exception to this exclusion was the nitrates, which had a communality of only 0.14. The nitrates were retained because they were one of the principal subjects of the study. Table 25 gives the results of a rotated, four factor solution of the correlation matrix using twenty-three of the twenty-six elements that were finally selected for use in the TTFA analysis. These four factors are sufficient to explain 79% of the variance in the input data matrix.

The first factor shows heavy factor loadings for SO_2, NO, NO_x, As, Se, $SO_4^=$, and fairly clearly represents the plant. The second factor shows no significant connection with the gaseous pollutants, and high factor loadings on the mineral elements, TSP, and sulfates. This is taken to represent a soil component. (Wind blown soil was visibly present in the air on many occasions, both from open fields and unpaved roads.) A third component was found to be tied to the alkali metals, chlorine, manganese, and phosphorus. No satisfactory source for this factor was identified; but it may have been related to the scrubber, as it showed some connection to the wind direction variable, or it may have resulted from contaminants from the impregnated filters used in conjunction with the teflon filters; with the latter more probable than the former. The fourth factor with significant loadings showed strong ties with bromine, sulfur, the mineral elements associated with soil, and a significant loading on total nitrates. This factor may be related to vehicular traffic, which was principally confined to the paved roadways at

TABLE 25. PRINCIPAL COMPONENT FACTOR ANALYSIS ROTATED FOUR FACTOR SOLUTION

	FACTOR LOADINGS				CONTRIBUTION TO TOTAL VARIANCE				COMMUNALITY
FACT.	1	2	3	4	1	2	3	4	
DIREC	0.49	0.03	0.18	0.04	0.24	0.00	0.03	0.00	0.27
SO2	0.89	0.06	0.15	0.33	0.79	0.00	0.02	0.11	0.92
SE	0.86	0.01	0.07	0.31	0.75	0.00	0.00	0.09	0.84
NOX	0.83	0.11	0.06	0.41	0.69	0.01	0.00	0.16	0.87
NO	0.81	0.12	0.01	0.39	0.65	0.01	0.00	0.15	0.82
NA	0.69	0.10	0.27	0.54	0.48	0.01	0.07	0.30	0.86
AS	0.64	0.17	0.39	0.57	0.41	0.03	0.15	0.32	0.91
SC	0.64	0.13	0.63	0.13	0.41	0.02	0.40	0.02	0.84
SO4=	0.57	0.46	-.11	0.57	0.32	0.21	0.01	0.32	0.86
U	0.56	0.42	0.32	0.26	0.31	0.17	0.10	0.07	0.65
BR	0.41	0.18	0.41	0.71	0.17	0.03	0.17	0.50	0.87
S	0.54	0.46	-.13	0.59	0.29	0.21	0.02	0.35	0.87
NO3-	0.04	0.00	0.14	0.34	0.00	0.00	0.02	0.12	0.14
TH	0.50	0.77	0.04	0.11	0.25	0.59	0.00	0.01	0.84
AL	0.21	0.74	0.30	0.43	0.05	0.55	0.09	0.19	0.87
PB	-.07	0.71	0.01	-.31	0.01	0.50	0.00	0.10	0.60
LA	0.28	0.68	0.40	0.52	0.08	0.47	0.16	0.27	0.97
TI	0.16	0.66	0.22	0.61	0.03	0.44	0.05	0.37	0.88
SI	0.26	0.65	0.38	0.59	0.07	0.43	0.14	0.35	0.98
FE	0.30	0.64	0.33	0.50	0.09	0.40	0.11	0.25	0.86
TSP	0.41	0.60	0.38	0.30	0.17	0.36	0.14	0.09	0.75
ZN	0.20	0.47	0.13	-.64	0.04	0.22	0.02	0.41	0.69
CO	0.05	0.54	0.02	-.46	0.00	0.29	0.00	0.21	0.50
CE	0.42	0.56	-.13	-.32	0.18	0.32	0.02	0.10	0.61
K	0.16	0.02	0.98	0.06	0.02	0.00	0.96	0.00	0.99
CA	0.04	-.09	0.92	0.16	0.00	0.01	0.84	0.03	0.88
CL	0.30	0.00	0.87	0.23	0.09	0.00	0.75	0.05	0.89
MN	0.40	0.14	0.83	-.05	0.16	0.02	0.69	0.00	0.87
MG	0.14	0.30	0.82	0.13	0.02	0.09	0.67	0.02	0.79
P	-.08	-.13	0.69	-.25	0.01	0.02	0.47	0.06	0.56
	PLANT	SOIL		AUTO &BKGD					

the edges of the study area to the north and south of the plant and will be further discussed later.

TARGET TRANSFORMATION FACTOR ANALYSIS

Target transformation factor analysis uses a linear combination of known source profiles (signatures) to reconstruct an observed data set. The particular computer code used in this work was developed by P. Hopke and co-workers at the University of Illinois-Urbana and has been extensively described in the literature under the acronym "FANTASIA". FANTASIA may be used to generate possible source vectors or signatures; to test known potential source vectors as real contributors to observed data; to predict missing values in either the observed data or in source vectors; and finally, to quantify the contributions of individual sources to individual samples within a data set. All of these features were utilized in some fashion in analyzing the Scholz test data; but only the last two will be discussed here.

The FANTASIA input data matrix consisted of the concentrations of twenty-six (26) elements for each of twenty-eight (28) filters. The data on the elemental concentrations were augmented with values for TSP from the other parallel hi-vol run; sulfate, nitrate, and nitric acid concentrations determined from the same hi-vol runs which provided the data on the elements; and average concentrations of NO, NO_x, and SO_2 at each sampling location for the time spans covered by the hi-vol samples. The latter averages were obtained by digital planimetry of the recorder traces of the various analyzers.

Source vectors used in regenerating the data were the measured emission strengths of the plant for the items listed above and the compositions obtained for the soil samples discussed earlier in the report. The predictive capabilities of FANTASIA were used to estimate concentrations of various elements and gases in the test vectors for the soil samples that were not available from the neutron activation analysis. Estimates were obtained in the same fashion for effective source strengths for the Scholz Plant for (1) elements such as arsenic, selenium, and chlorine which, because of their volatility, would have been under-represented in the actual source samples; and (2) for sulfates, nitrates, and NO which would or could change from the measured source strengths by reactions after discharge from the stack. Because of the linear nature of the model, the estimates obtained in this fashion represent averages and cannot provide time/distance dependences for reactive components given the small number of available samples. These estimates indicate that approximately forty percent (40%) of the NO emitted by the plant had reacted to form NO_2 by the time it reached the downwind sampling sites, and that the ratio of sulfate to SO_2

associated with the plant emissions had increased by perhaps a factor of two within the area encompassed by the sampling sites. Given the wind velocities that prevailed through most of the program, these increased sulfate concentrations in the plume represent conversion rates of SO_2 to SO_4 of about 0.25 percent per hour - a rate which is consistent with those obtained in other investigations.

When the measured source concentrations were tested as being a possible source of a portion of the particulate matter found on the hi-vol filters a very good match was found for most elements - within ±30% or better in most cases for the non-volatile, non- reactive components. However, poor agreement was found for the elements calcium, sodium, and magnesium. In the case of the latter elements, the program suggested that the source concentrations were substantially higher than the values obtained from the analyses of the flue gas particulate samples. These elements are present in high concentrations in the scrubber liquor and we believe that the higher source strengths that FANTASIA would assign to them arises from their addition to the plant plume by the scrubber. The higher values for the source concentrations of these elements that were suggested by the target testing were used in the final regeneration of the ambient data set for purposes of quantifying the plant impact.

Table 26 summarizes the final source vectors used to regenerate the data. Table 27 provides a summary of the regenerated data. The table includes the average contribution of each source (soils and plant) to the samples; the average observed concentration for each variable, the average total predicted concentration from the combination of sources, and the average error in the individual reproductions. The average errors are somewhat misleading in that very large errors will be obtained where zeros occur in the data from concentrations below the detection limits. Comparison of the relative quantities of the four soil samples predicted for individual filters added greatly to our confidence in the significance of the FANTASIA results. The soils found geographically nearest the samplers or immediately upwind of them were assigned the greatest contribution in almost all cases. Because of the linear model on which factor analysis works, the contribution of a source to any particular sample's concentrations can be obtained for all of the items in the source vector by multiplying the vector by an appropriate weighting factor. The weighting factors corresponding to the twenty-eight filter samples are given in Table 28.

With respect to the principal variables of interest in this study, FANTASIA assigned none of the nitric acid, and approximately 15% of the nitrates, 20% of the sulfates, 95% of the SO_2, 95% of the NO and 85% of the NO_2 associated with the samples to the plant. Table 29 gives measured values of several of the

TABLE 26. TTFA INPUT PLANT AND SOIL SOURCE VECTOR

ELEMENT	CYC	WAQ	NAQ	LO2	SAQ
AL	3773	7.582	53.4	72	45.2
SI	4142	96.75	14.4	112.4	121.3
P	76	2.815	4.53	4.96	4.7
S	12280	79.4	64.8	42.7	78.3
CL	9128	0	0	7.58	.3
K	504	4.94	6.58	6.38	6.9
CA	164	1.09	15.4	14	19.5
TI	143	1.33	4.92	8.79	8.6
MN	8.3	.3	4.55	.7	3.6
FE	5663	25.2	39.5	31.7	31.3
AS	182	.2	.029	.013	.019
SE	29	.004	.0013	.0019	.0014
BR	151	.0125	.013	.0087	.016
HG	108	0	.1	.46	.12
MG	346	1.87	3.53	9.4	6.3
NA	11205	1.13	1.05	.74	.76
SM	.446	.0125	.0061	.013	.025
U	.558	.011	.009	.012	.0095
TH	.672	.022	.021	.028	.02
LA	3.3	.12	.08	.12	.2
SC	2.1	.0125	.016	.017	.011
EU	.105	.0049	.0084	.0056	.0052
NITRIC AC	0	60	74	52	66
NITRATE	1900	20	17	8.7	17
TSP	70000	2150	2310	1610	2300
SO2	1776000	176	109	40	150
SO4	33300	193	148	90	180
NO	301900	0	0	0	0
NOX	479900	168	143	40	130

TABLE 27. TTFA ANALYSIS SUMMARY

	ELEMENT	1002C21	SOIL WAQ	SOIL NAQ	SOIL L02	SOIL SAQ	AVG PRED	AVG OBS	AVG %
1	AL	0.730E-01	0.490E-01	0.469E-01	0.578E+00	0.112E+00	0.859E+00	0.885E+00	0.142E+02
2	Si	0.801E-01	0.626E+00	0.126E-01	0.902E+00	0.302E+00	0.192E+01	0.192E+01	0.150E+01
3	P	0.146E-02	0.182E-01	0.398E-02	0.398E-01	0.117E-01	0.752E-01	0.637E-01	0.106E+03
4	S	0.238E+00	0.513E+00	0.569E-01	0.343E+00	0.195E+00	0.134E+01	0.137E+01	0.747E+01
5	Cl	0.177E+00	0.000E+00	0.000E+00	0.608E-01	0.807E-03	0.238E+00	0.263E+00	0.186E+03
6	K	0.975E-02	0.320E-01	0.577E-02	0.512E-01	0.171E-01	0.116E+00	0.135E+00	0.381E+02
7	Ca	0.318E-02	0.704E-01	0.135E-01	0.112E+00	0.485E-01	0.248E+00	0.266E+00	0.672E+02
8	Ti	0.277E-02	0.862E-02	0.432E-02	0.705E-01	0.214E-01	0.108E+00	0.278E-01	0.186E+03
9	Mn	0.160E-03	0.203E-02	0.399E-02	0.550E-02	0.902E-02	0.207E-01	0.157E-01	0.897E+03
10	Fe	0.110E+00	0.163E+00	0.346E-01	0.254E+00	0.778E-01	0.639E+00	0.570E+00	0.589E+02
11	As	0.353E-02	0.133E-02	0.254E-04	0.104E-03	0.478E-04	0.503E-02	0.475E-02	0.803E+02
12	Se	0.565E-03	0.252E-04	0.117E-05	0.153E-04	0.353E-05	0.610E-03	0.164E-02	0.288E+04
13	Hg	0.209E-02	0.000E+00	0.902E-04	0.372E-02	0.296E-03	0.620E-02	0.389E-02	0.451E+03
14	Mg	0.669E-02	0.118E-01	0.310E-02	0.756E-01	0.156E-01	0.113E+00	0.111E+00	0.125E+03
15	Na	0.217E+00	0.728E-02	0.918E-03	0.590E-02	0.188E-02	0.233E+00	0.289E+00	0.292E+03
16	Sm	0.863E-05	0.806E-04	0.532E-05	0.105E-03	0.627E-04	0.262E-03	0.145E-03	0.205E+03
17	U	0.108E-04	0.724E-04	0.788E-05	0.976E-04	0.237E-04	0.212E-03	0.869E-04	0.602E+02
18	Th	0.130E-04	0.143E-03	0.187E-04	0.224E-03	0.490E-04	0.448E-03	0.242E-03	0.206E+03
19	La	0.645E-04	0.773E-03	0.698E-04	0.976E-03	0.494E-03	0.238E-02	0.601E-03	0.705E+03
20	Sc	0.415E-04	0.805E-04	0.143E-04	0.138E-03	0.264E-04	0.301E-03	0.170E-03	0.152E+03
21	Eu	0.203E-05	0.314E-04	0.733E-05	0.452E-04	0.128E-04	0.988E-04	0.207E-04	0.650E+03
22	NA	0.000E+00	0.379E-02	0.643E-03	0.416E-02	0.163E-02	0.102E-01	0.779E-02	0.114E+03
23	N3	0.372E-03	0.127E-02	0.150E-03	0.688E-03	0.432E-12	0.248E-02	0.249E-02	0.234E+03
24	Ms	0.135E-01	0.139E+00	0.203E-01	0.129E+00	0.571E-01	0.359E+00	0.348E+00	0.372E+02
25	S2	0.329E+00	0.114E-01	0.957E-03	0.355E-02	0.376E-02	0.349E+00	0.298E+00	0.684E+03
26	S4	0.644E-02	0.125E-01	0.130E-02	0.703E-02	0.450E-02	0.318E-01	0.316E-01	0.111E+02
27	NO	0.584E-01	0.167E-04	0.000E+00	0.708E-07	0.000E+00	0.584E-01	0.621E-01	0.476E+03
28	NX	0.929E-01	0.109E-01	0.126E-02	0.327E-02	0.315E-02	0.111E+00	0.110E+00	0.652E+02

TABLE 28. WEIGHTING FACTORS FOR TTFA REGENERATION OF AMBIENT DATA FROM SOURCE VECTORS (TABLE 26).

	WEIGHTING FACTOR FOR SOURCE INDICATED					
FILTER ID	POWER PLANT	SITE 16 SOIL	SITE 13 SOIL	SITE 2 SOIL	SITE 15 SOIL	SAMPLE SITE
5	1.398E-5	.00944	.00245	.00441	-.00359	16
7	1.031E-5	.01135	.00486	.01409	-.00514	1
8	2.826E-6	.00091	-.00359	-.00054	.00141	16
9	9.55E-7	.01022	.00557	.01751	-.01218	15
10	1.734E-5	-.00618	.00191	-.00776	.01733	3
11	9.036E-7	.00653	-.00313	.00949	-.00419	16
12	-3.98E-7	.00164	-.00166	.00904	.00104	3
13	1.030E-5	-.01374	.00238	.00612	.01298	15
14	-1.04E-6	.01092	.00089	.01597	-.01145	16
15	-6.68E-6	.03791	-.00381	.07018	-.05861	5
16	2.83E-6	.01173	.00012	.00916	-.00242	4
17	-2.04E-6	.01557	-.00066	.01443	-.01131	13
18	7.81E-6	.00709	-.00252	.02687	-.00743	1
19	9.183E-5	-.00661	-.00267	.02241	.00923	6
21	1.257E-5	.00083	-.00135	.00098	.00895	2
22	8.658E-6	.00987	-.00387	.02842	-.00669	16
25	2.923E-5	-.01224	.00369	-.01663	.04353	13
26	9.701E-5	.05284	-.02793	.08061	-.04746	9
27	1.592E-5	.01848	.01298	-.00451	-.00504	8
28	1.399E-5	.00608	.00149	-.00144	.00753	11
29	6.807E-6	.00944	.00908	-.00222	.00511	3
30	2.059E-5	.00508	.00902	.01705	.01924	15
31	4.322E-6	.00159	.00724	-.01443	.02023	13
32	4.139E-6	.00138	.00149	-.00412	.01133	10
33	1.452E-6	.00397	.00322	-.00535	.00669	15
34	6.299E-5	.00271	-.00781	.00898	.01254	11
35	2.031E-5	.01022	.00878	-.00428	.00178	15
36	9.490E-5	-.02591	.00836	-.03567	.06446	12

TABLE 29. COMPARISON OF SELECTED RESULTS OF TARGET TRANSFORMATION FACTOR ANALYSIS WITH MEASUREMENTS

DATE	SITE #	TTFA SCHOLZ TSP FRACT.	MEAS. TOTAL NITRATE UG/DNM3	TTFA SCHOLZ NITRATE UG/DNM3	RESID. NITRATE	MEAS. TOTAL BR NG/DNM3	TTFA SCHOLZ BR NG/DNM3	RESID. BR	TEFLON FILTER SULFATE UG/DNM3	TTFA TOTAL SULFATE UG/M3	TTFA SCHOLZ SULFATE UG/M3	SCHOLZ SULFATE FRACT.	MEAS. SO2 PPB	TTFA PRED. SO2, PPB
1/28	6		1.74						3.86				NA	NA
1/29	6		1.33						1.8				.05	NA
1/30	1	.1	1.12	.065	1.055	18.9	1.22	17.68	3.06	2.31	.343	0.11	2.41	19
	16	.19	1.30	.088	1.212	3.04	1.65	2.19	2.83	2.39	.465	0.16	0	25.3
2/2	3	.27	0.44	.059	.381	.62	1.11	0.00	1.99	2.12	.577	0.29	48.15	30.9
	16	.08	0.25	0	.25	1.21	0	1.21	1.37	1.2	.094	0.07	0	5.7
	15	.01	0.20	.016	.184	3.36	.29	3.07	2.04	2.16	.032	0.02	8	2.96
2/3	3	0	0.42	0	.42	.36	0	0.36	.98	1.04	0	0.00	.46	0
	16	.02	0.48	.013	.467	1.96	.24	1.72	.75	.9	.03	0.04	8	2.13
	15	.12	0.87	.035	.835	2.73	.65	2.08	1.04	.926	.343	0.33	15.3	17.6
2/4	4	.03	1.60	.033	1.567	7.78	.61	7.17	1.82	2.75	.094	0.05	2.68	6.93
	16	0	1.26	0	1.26	.83	0	0.83	1.56	1.53	0	0.00	1.25	0
	5	0	1.86	0	1.86	6.21	0	6.21	1.84	2.08	8	0.00	1.26	0
	14		NA										40.15	NA
2/5	1	.05	1.69	.033	1.657	7.27	.62	6.65	2.36	2.26	.26	0.11	19.24	14.3
	6	.35	1.45	.426	1.024	12.8	7.98	4.82	3.91	5.02	3.06	0.78	175.01	157
	13	0	1.95	.002	1.948	2.24	.03	2.21	1.86	2.06	0	0.00	8	8
2/6	12		NA						.91				NA	NA
2/9	2	.16	1.50	.072	1.428	8.7	1.36	7.34	2.24	2.08	.418	0.19	7.31	22.8
	16	.05	1.08	.095	.985	5.26	1.77	3.49	2.81	2.9	.288	0.10	22.46	16.3
	13		NA										16.3	NA
	1		NA										5.25	NA
2/10	8	.17	0.44	.059	.381	1.19	1.1	0.00	4.27	4.72	.53	0.12	23.91	30.8
	13	.16	0.98	.259	.721	2.06	4.85	-2.79	5.93	5.9	.972	0.16	5.64	54.04
	9	.23	1.12	.546	.574	34.8	10.2	24.60	7.59	7.77	3.23	0.43	145.01	167.6
2/11	15	.2	0.78	.057	.723	1.23	1.06	0.00	5.02	4.99	.685	0.14	49.7	39.03
	3	.06	0.51	.002	.508	1.09	.044	1.05	4.46	4.12	.226	0.05	11.71	14.9
	13	.05	0.93	0	.93	7.4	0	7.40	4.64	3.92	.144	0.03	0	10.8
	13		NA										NA	NA
2/12	11	.15	0.77	.044	.726	.25	.82	0.00	2.92	3.1	.465	0.16	39.31	26.1
	10	.06	1.47	.007	1.463	4.71	.13	4.58	2.35	2.31	.138	0.06	5.91	8.97
	15	.03	0.69	0	.69	1.42	0	1.42	2.18	2.03	.048	0.02	0	4.29
2/13	11	.34	1.11	.289	.821	10.1	5.42	4.68	4.46	4.52	2.1	0.47	113.01	109
	12	.43	1.60	.463	1.137	9.97	8.68	1.29	7.66	7.93	3.16	0.41	144.01	165.8
	15	.22	1.25	.099	1.151	8.95	1.85	7.10	4.48	3.9	.676	0.15	.32	37.4

variables of particular interest together with the concentrations of them attributed to the plant by TTFA. A plot of the regenerated sulfate concentration from FANTASIA versus the original data is given on a filter by filter basis in Figure 33. Figure 34 shows a plot of the sulfate concentration in the ambient that the TTFA attributed to the plant versus the observed total sulfate concentration. This figure shows that between 0 and 50% of the sulfate found on the filters was attributed to the Scholz Plant. In general, the fraction assigned to the plant decreased with distance from the plant as one would intuitively expect. The percentages quoted above are biased in-so-far as their representation of the net contribution of the plant to the ambient concentrations are concerned in that the samplers tended to be located preferentially at locations over which the plant's plume would have been expected to pass.

Better estimates of the net impact of the plant in terms of sulfates and nitrates can be obtained by grouping the samples in quadrants defined by the relative wind direction with respect to the plant location. Samplers located in the upwind quadrant had no contribution from the plant, either real or in the regenerated data. Samplers located in quadrants centered at 90 degrees with respect to the mean wind direction showed some impact of the plant; and samplers located in the downwind quadrant showed the greatest impact in the FANTASIA results. By weighting the plant contributions singly for upwind and downwind samplers, and twice for crosswind samples (two crosswind quadrants, one each of the others) one can obtain a better estimate of the true average impact of the plant on its immediate surroundings. When weighted in this fashion, the plant contribution to the net sulfate in the area drops from 20% to about 15%. The net contributions to nitrate show a similar fractional drop from about 15% to 11%.

Iterative solutions for potential un-identified source vectors starting from "uniqueness test" solutions for Ca, Mg, K, Na, and Cl, converged to a common vector which has these elements plus a sulfate component in roughly stoichiometric quantities for simple salts. Because the filters were in intimate contact with salt impregnated filters during sampling, we suspect that this vector, which the correlation analysis also showed, represents contaminants from them. Alternatively, this vector may represent emissions from the scrubber as previously mentioned. In either case, contribution to total mass associated with this component was rather small.

A second reconstruction of the data set was made using a four factor solution based on an average soil composition from the four soil samples, the measured source emission profile used in the previously described reconstruction, the "salt" vector described above, and a source vector based on "uniqueness test" solutions which conveyed starting from Bromine and nitric acid.

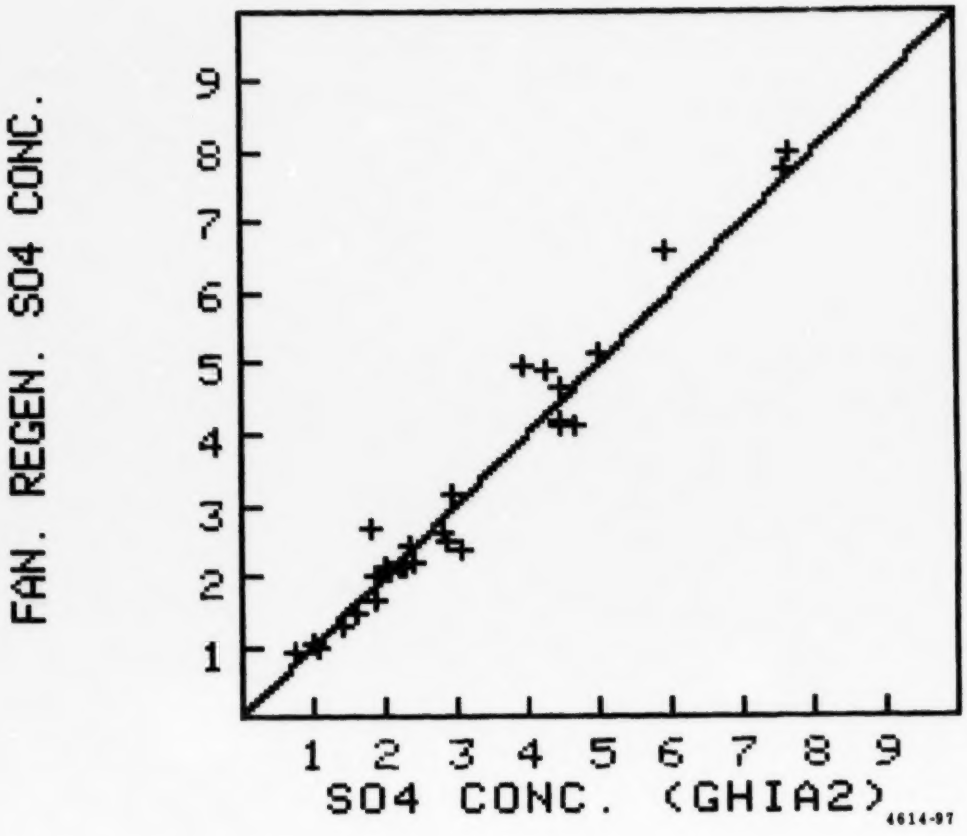

Figure 33. Comparison of the TTFA regenerated ambient sulfate concentrations and the measured concentrations.

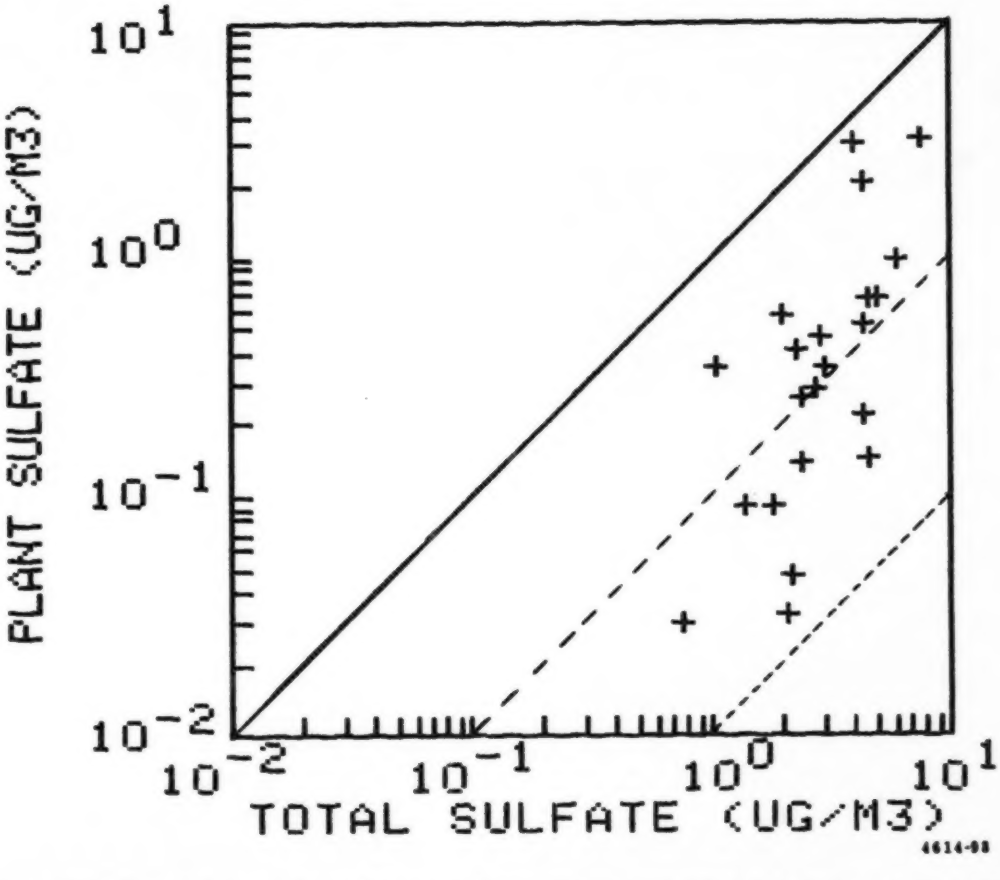

Figure 34. Comparison of the ambient sulfate concentrations attributed to the plant by TTFA and the measured total sulfate concentrations.

This combination resembled that suggested by the correlation matrix factor analysis results. The reconstructions obtained inthis fashion made no material difference in the portions of the sulfates and nitrates attributed to the Scholz plant.

Some portion of the sulfate associated with the soils may have originated from the plant and represent previously deposited material that was resuspended with the windblown soil. The plant had been operating for a number of years with virtually no particulate emissions other than condensed sulfuric acid. Thus one would not expect to find flyash associated with any such resuspended sulfate, or if it were present it would not be there in quantities approaching the ratios to sulfate and gases that were obtained in these tests. (The flyash concentration was abnormally high for these tests as a result of the deliberate detuning of the ESP's.)

COMPARISON WITH DISPERSION MODELS

ISC Model

Source emission data and meteorological data for each test day were used with the Industrial Source Complex model[63] to predict hourly average concentrations through each test day at all downwind sampling sites. The model predictions were only made for the plant contributions to SO_2 and NO_x; however, values for other parameters (e.g. Sulfate) can be obtained by scaling the SO_2 and NO_x values for the relative source strength of the parameter of interest. The results of the ISC model runs are given in Table 30 together with the measured results from the sampling program.

At moderate distances from the plant the ISC predictions were reasonably close to the measured values on some occasions. However, at locations that were relatively close to the plant it always severely underpredicted the measured values. In many cases, the underpredictions were made at times when the relative wind direction was such that the model placed the plume directly over the sampling location but predicted zero ground level concentrations. Thus the low predicted values must have been due to poorly modeled plume rise effects or to much higher turbulence levels than the standard Pasquill-Gifford relationships predict in light of the temperature inversions that existed through most of the test. It is now recognized that the Briggs plume rise equations used in the ISC model overpredict plume rise by about a factor of two.[69] The higher turbulence could be due to either the general rolling topography in some cases or to building wake effects in the immediate vicinity of the plant, or both. Because the inversions were located at much higher altitudes than the maximum height the plume would be expected to

TABLE 30. ISC MODEL PREDICTIONS OF SO_2 AND NO_x COMPARED WITH MEASURED VALUES

DATE & TIME	SO2		NOX		SO2		NOX		SO2		NOX	
	PRE	MEA	PRE	MEA	PRE	MEA	PRE	MEA	PRE	MEA	PRE	MEA
2/2	SITE 3				SITE 15							
12	110		20	6								
13	55	58	10	13	9	0						
14	105	116	19	17	0	0						
15	44	199	8	26	0	0						
2/3	SITE 3				SITE 15							
8					0	0						
9	0	1		2	0	0						
10	0	1	0	6	0	0						
11	0	0	0	4	0	0						
12	0	0	0	4	76	57						
13	0	0	0	4	3	50						
14	0	0	0	2	9	79						
15	0	0	0	2	111	129						
16					0	97						
17					0	25						
2/5	SITE 6				SITE 1							
8					0	193	0	113				
9	0	345	0	96	0	35	0	21				
10	0	494	0	101	0	20	0	30				
11	0	164	0	15	0	57	0	21				
12	0	32	0	9	0	53	0	19				
13	0	33	0	8	0	12	0	9				
14	0	29	0	8	0	9	0	9				
15					0		0	8				
2/9	SITE 2				SITE 1				SITE 16			
8					0	278	0	13	0	14		
9					0	6	0	0	0	446		
10	0	16	0	9			0		0	11	0	
11	0	17	0	8	0	8	0	4	0	0	0	
12	0	19	0	8	0	10	0	8	0	8	0	
13	0	76	0	8	0	24	0	23	0	11	0	
14	0	38	0	9	0	11	0	17	0	26	0	
15	296	45	50	19	0	1	0	24	2	0	0	
16	0	33	0	13	0	5	0	28				

DATE & TIME	SO2		NOX		SO2		NOX		SO2		NOX	
	PRE	MEA	PRE	MEA	PRE	MEA	PRE	MEA	PRE	MEA	PRE	MEA
2/10	SITES 7&8				SITE 9				SITE 13			
8					0	978	0	86	0	0		
9					0	489	0	199	0	0		
10	21	157	3	51	0	861	0	184	0	0		
11	0	6	0	6	0	260	0	43	0	0		
12	19	26	3	13	0	117	0	6	0	0		
13	35	100	5	30	0	86	0	39	0	0		
14	0	46	0	15	0	787	0	122	0	0		
15	25	86	3	17	0	598	0	85	0	0		
16	27	40	3	8	0	867	0	139	0	0		
17					0	752	0		0	0		
2/11	SITE 15				SITE 3							
10					0							
11	101		23	30	0							
12	0	46	0	41	11	263						
13	100	106	14	17	4	309						
14	42	29	6	9	29	292						
15	40	6	6	6	28	429						
16	0	3	0	2	0	400						
17					34	114						
2/12	SITE 10				SITE 11							
9	0	20	0	21								
10	0	17	0	17								
11	0	14	0	15								
12	76	17	12	13	0	49	0					
13	0	17	0	11	0	206	0	41				
14	0	17	0	11	0	74	0	13				
15	0	17	0	9	0	92	0	17				
16	0	14	0	9	0	103	0	24				
17					0	209	0	41				
2/13	SITE 11				SITE 12							
8					0	586	0	113				
9						744		265				
10	4	166	1	30	0	661	0	179				
11	177	446	25	14	0	257	0	113				
12	0	252	0	23	0	34	0	160				
13	0	31	0	6	0	252	0	41				
14	0	73	0	9	0	518	0	118				
15	0	203	0	37	0		0	90				
16	0	109	0	24								

reach based on the Brigg's relationships, stability classes based on the existence of the inversions may have been misleading with regard to processes within the actual transport layer.

Comparisons of Dispersion Estimates with Factor Analysis Results

The ISC model results presented in the last paragraphs were rather too specific either for comparison with the results of the TTFA methodology or for estimating the area wide impact of the plant. When the concentrations of sulfate attributed to the plant were plotted versus downwind distance the trends in the data appeared to be similar to those that the simplistic dispersion model described by Turner[70] would predict. Calculations of predicted downwind sulfate concentrations for a four hour averaging time were made based on methods described by Turner using average meteorological conditions for each day (or group of days, when conditions were similar). The results of these calculations are shown in Figure 35 together with the concentrations assigned to the plant. In the figure the results of upwind samples are indicated by the letter "u", those for crosswind samples by the letter "c", and those for downwind samples by the letter "D". Upwind samples are defined here as those for which the samplers lie within the quadrant centered on the mean direction from which the wind was flowing during the sampling period. Downwind samples are similarly defined as being taken by samplers located within 45 degrees of the direction toward which the wind was blowing during the sampling period. Samples taken at stations located outside these two quadrants were defined as crosswind samples. Because of the limited number of samples that were available, finer angular resolution of sampler location is not justified. Figure 36 illustrates the data and dispersion model estimates for SO_2. Comparison of the figures reveals that the model overpredicts the SO_2 concentrations by about a factor of two, while the observed sulfate concentrations are fit reasonably well, which illustrates the apparent relative increase in sulfate concentrations in the plume as compared to the in-stack data.

Because of swings in wind direction through the day, samplers designated as downwind would tend to have been impacted by the plant's plume at least part of the time through the sampling day; and in fact, they did all show some contribution from the plant. Further, the samples assigned the greatest contributions from the plant were all in the class defined as downwind. Moreover, the peak concentrations ascribed to the plant fell close to the dispersion model predictions at most downwind distances; and none of the upwind samples were assigned any contribution from the plant - a somewhat reassuring result. In the cases of those samples classified as crosswind, the values tended to fall near or below the dispersion model predictions. It should be noted that although a sample may have been classed as "cross-

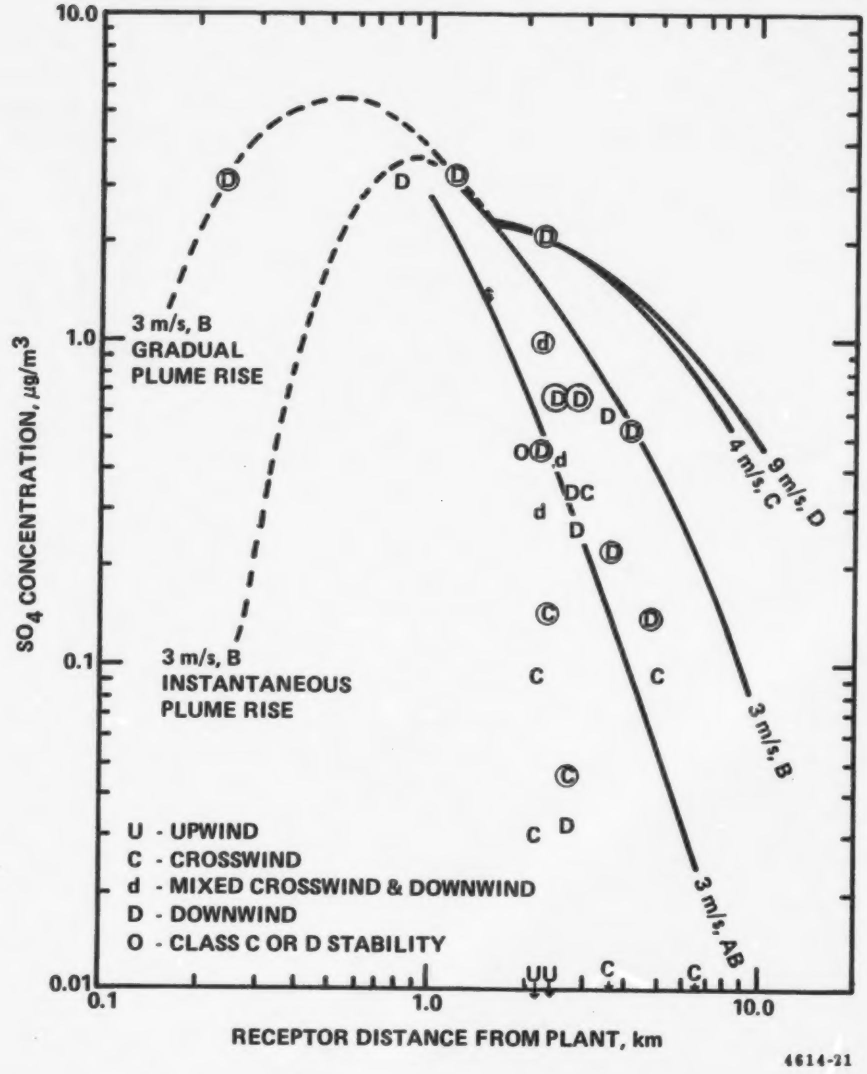

Figure 35. Measured and dispersion model predictions of Scholz plant sulfate concentrations.

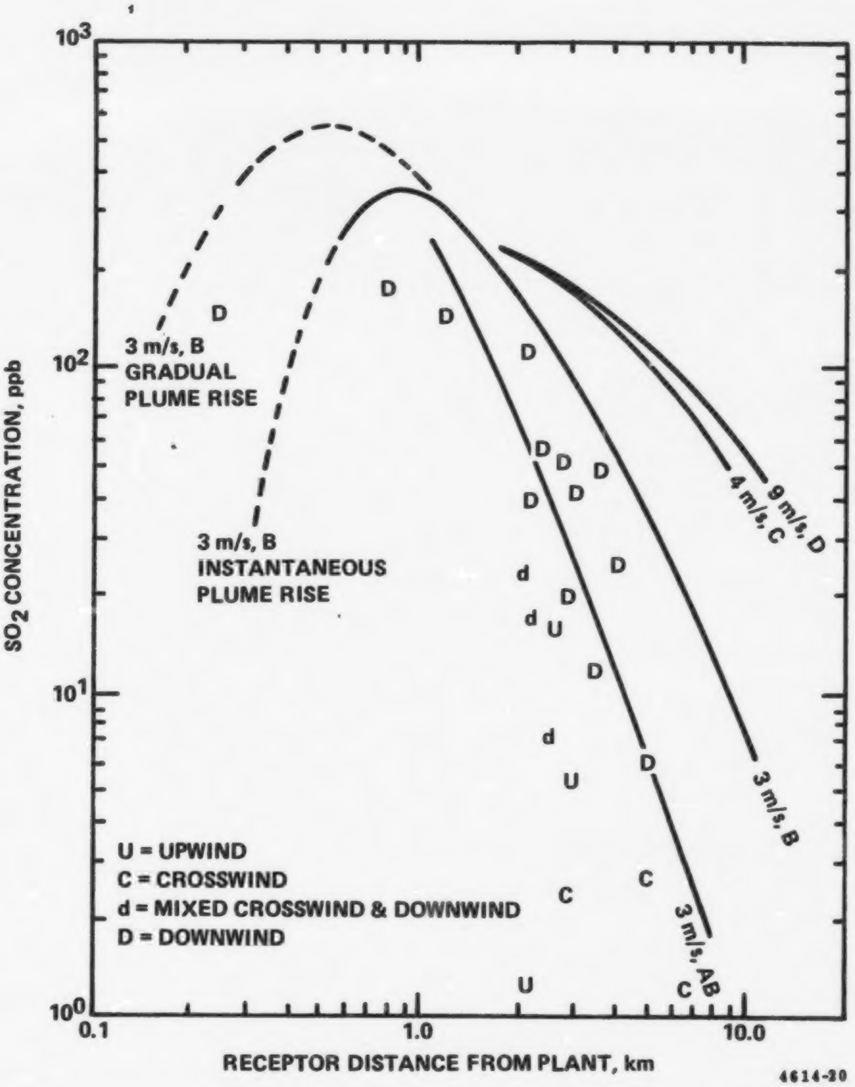

Figure 36. Measured and dispersion model predictions of plume SO_2 concentrations.

wind" based on the mean wind direction, the plume may well have passed over the location at some time(s) during the day, and in fact did so in many cases.

In reviewing the FANTASIA reproductions of the observed data, we found that the average values in the reproduced data for most of the variables were close to the corresponding average in the measured data. The variables bromine and nitric acid on the other hand were consistently underpredicted in the regenerated data. These two variables were among those which the correlation matrix analysis had suggested to belong to a source other than the plant, scrubber, and soil. Plots of the concentrations of bromine and nitric acid versus the distance of the sampler from major traffic arteries are shown in Figures 37 and 38. There is a great deal of scatter in the data shown in these plots, and no clear trends are apparent. However, if the data that were taken when the wind was from the town of Chattahoochee (winds from NE to ENE) are omitted, there does appear to be a clear trend toward decreasing concentrations with increasing distance from major roads, suggesting that bromine and nitric acid have large automotive contributions. The relatively heavy traffic in the more populated area would increase the concentrations of an automotive component resulting in the high values when the wind was out of Chattahoochee.

The plant produced a significant contribution to the bromine concentrations, thus the trend for bromine should be more pronounced if the plant contribution is subtracted. This occurs as shown in Figure 39 in which the TTFA values of the plant bromine concentrations have been subtracted from the totals.

Figure 40 shows the available data for the element lead. Unfortunately, the lead concentrations were below the detection limit for almost all samples, and in fact, were below the conventionally described detection limit set by the analytical laboratory for the data shown, although the values were reported. Even though the values are uncertain, they do appear to support a trend toward higher concentrations near roadways. Therefore we conclude that the majority of the bromine, nitric acid, and lead in the samples had an automotive origin. Such conclusions regarding lead and bromine are certainly reasonable as these two elements have repeatedly been found to be associated with an automotive component in ambient particulate matter to the extent that they are frequently used to identify an automotive component.

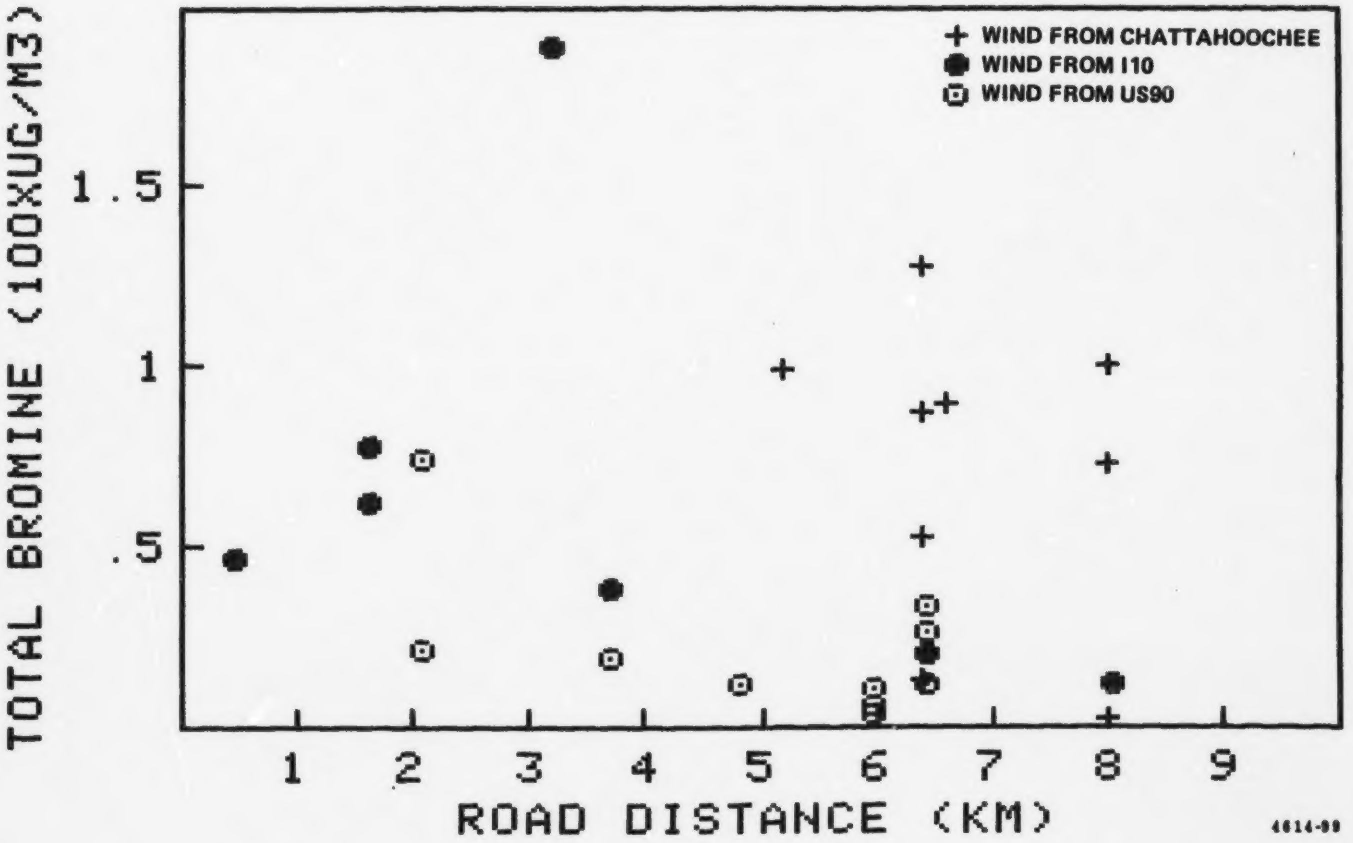

Figure 37. *Ambient bromine concentrations plotted versus distance from major upwind vehicular traffic sources.*

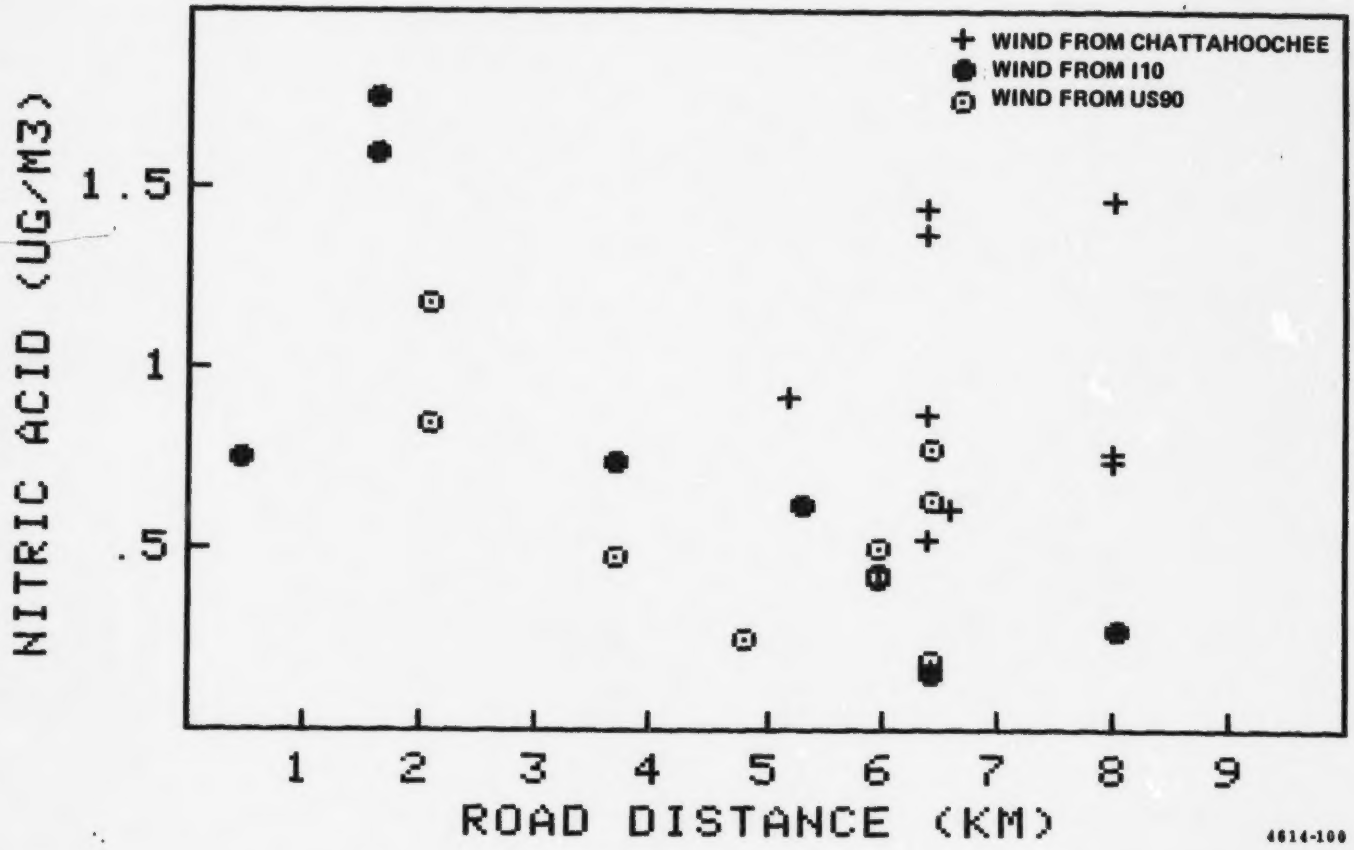

Figure 38. Ambient nitric acid concentrations versus distance from major upwind vehicular traffic sources.

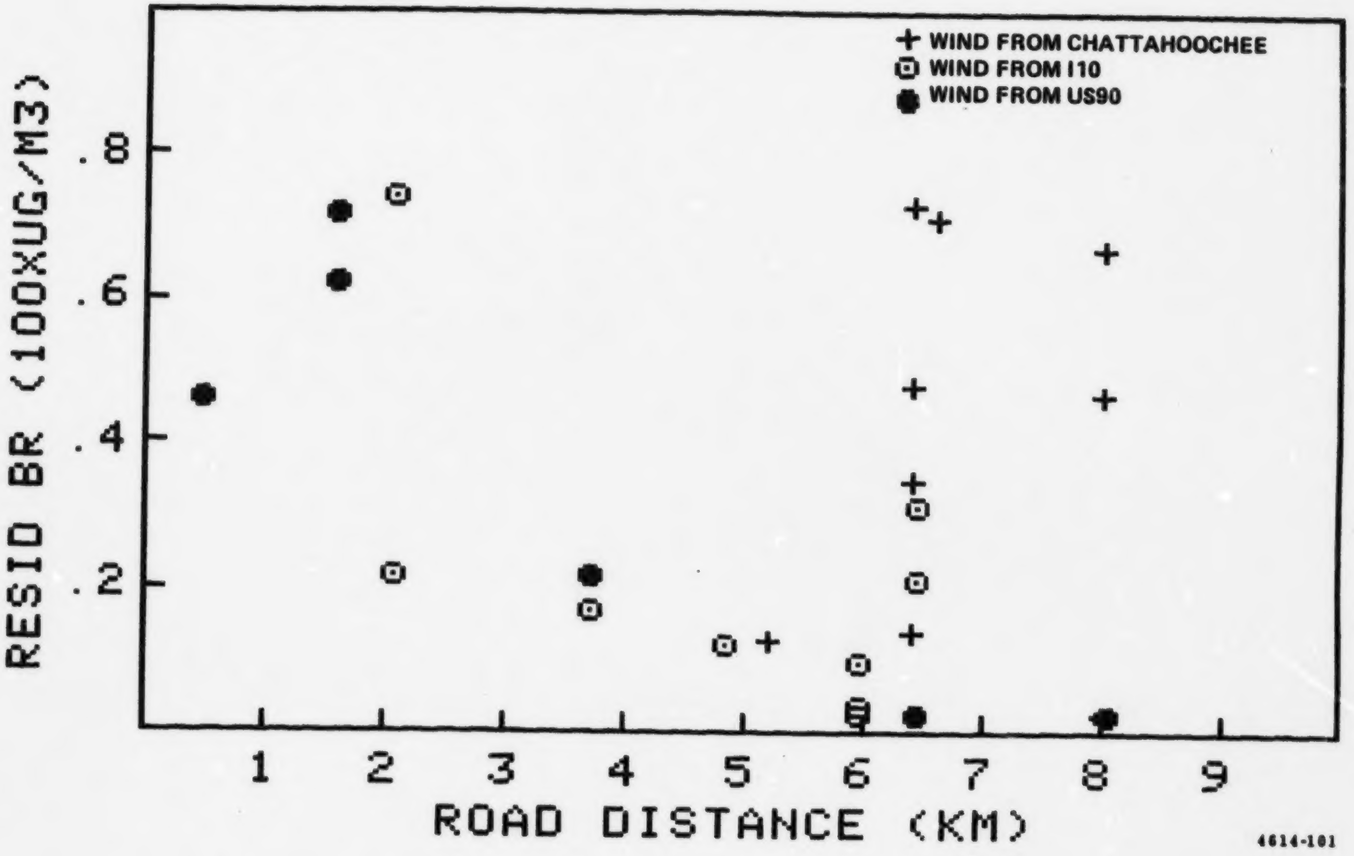

Figure 39. *Residual bromine concentrations after subtraction of TTFA estimates of the plant contributions versus distance from major traffic sources.*

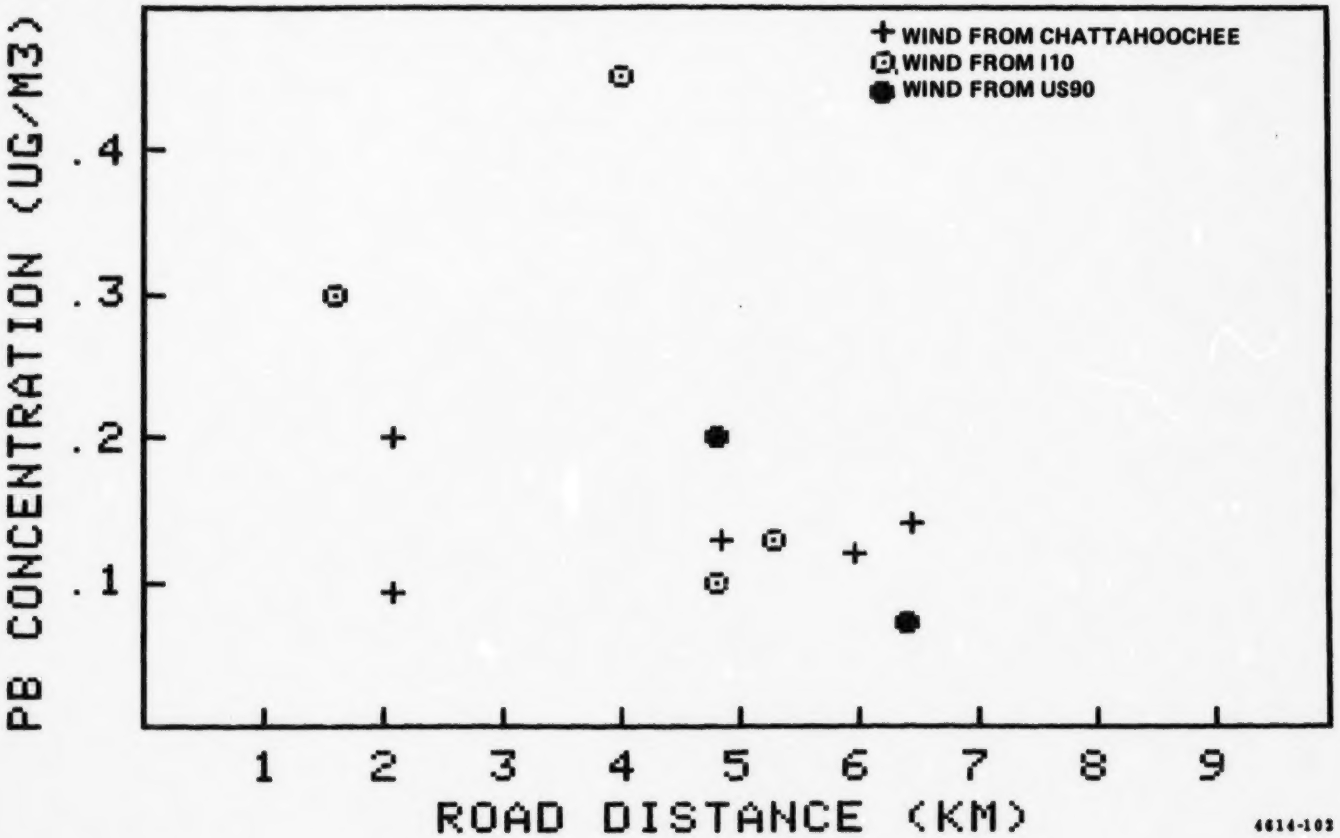

Figure 40. . *Lead concentrations versus distance from major traffic sources.*

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